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Water Power

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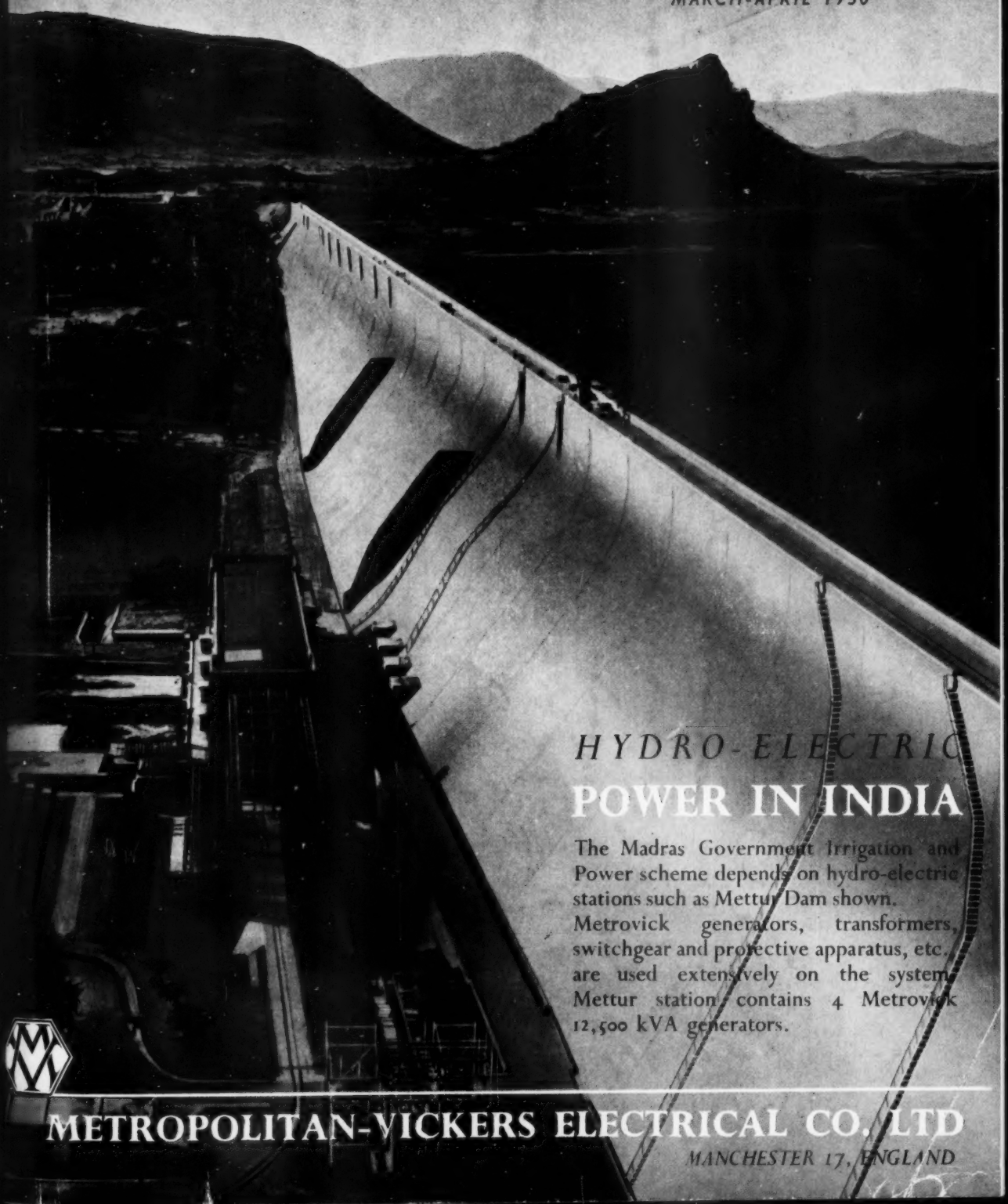
INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

MARCH-APRIL 1950



HYDRO-ELECTRIC

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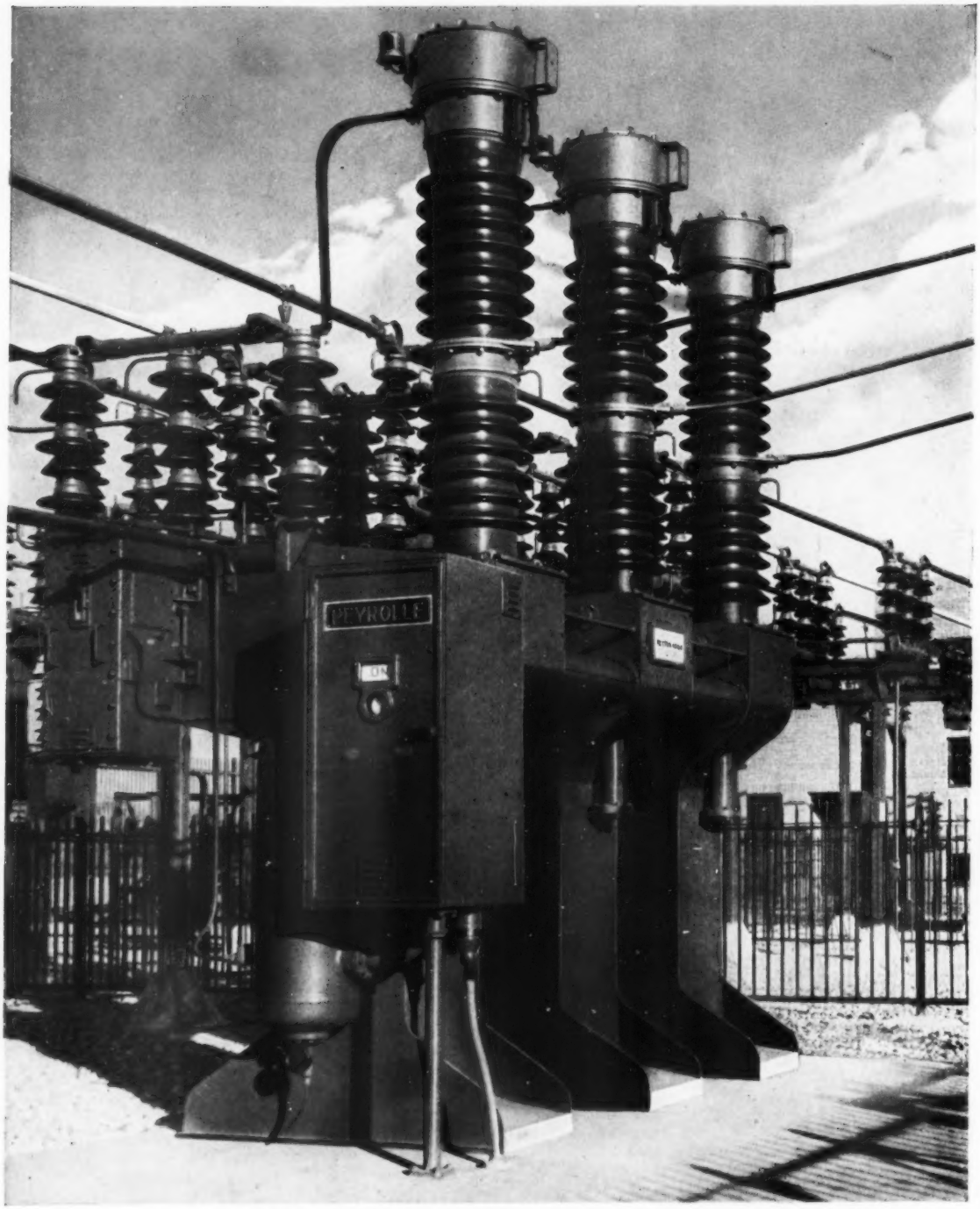

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Published by
Tothill Press Limited,
33 Tothill Street, Westminster, London, S.W.1.
Telegrams: Ishbuilder, Parl, London. Telephone: Whitehall 9233 (12 lines).

NEWCASTLE-ON-TYNE: 4 Royal Arcade, Pilgrim Street. Telephone: Newcastle 22239.
MANCHESTER: Century House, St. Peter's Square. Telephone: Central 3101.
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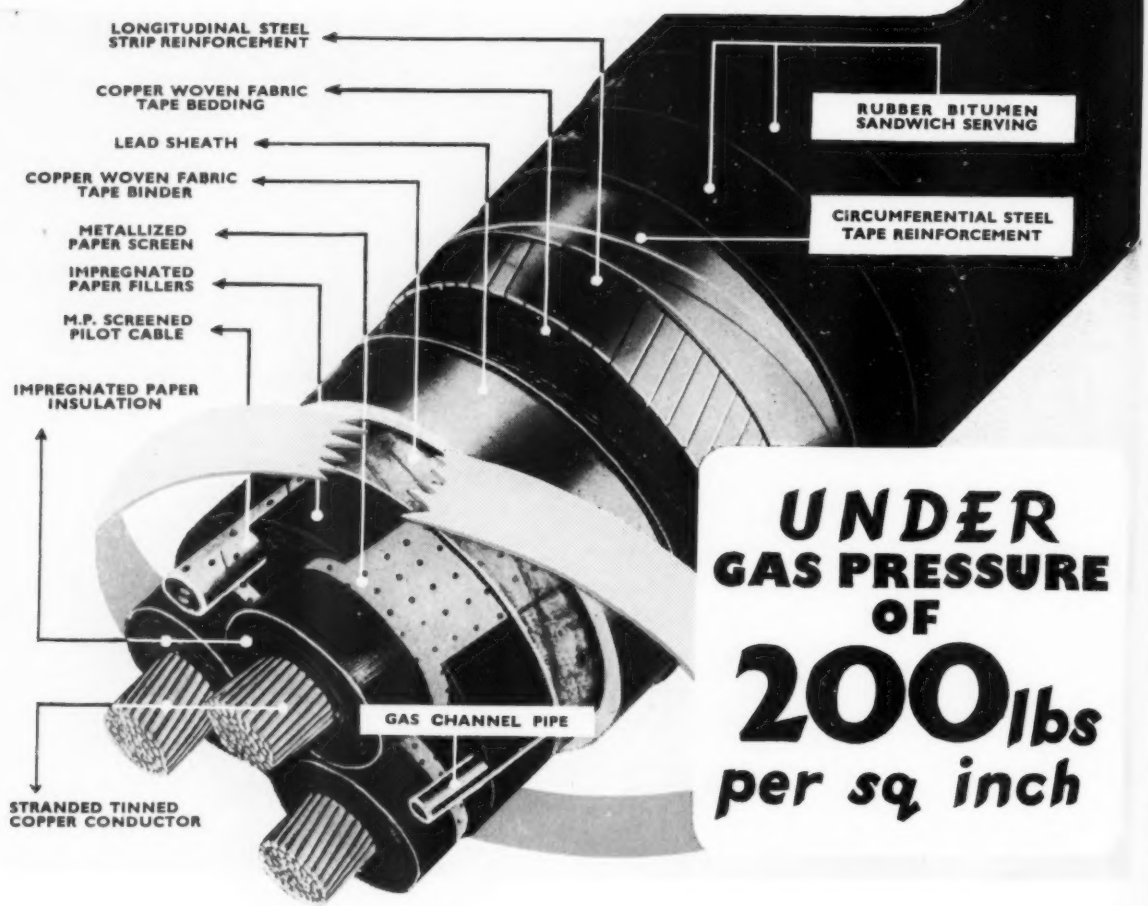
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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Discussions

WITHIN the next few months many of the problems facing those concerned with power supply — and in particular hydro-electric development — will be aired in open discussion at several important conferences of engineers. In Great Britain we have the British Electrical Power Convention at Harrogate at the end of June, which will be followed closely by the *Conference Internationale des Grands Reseaux Electriques* (C.I.G.R.E.), in Paris.

Then the Fourth World Power Conference will meet in London; an occasion of great significance in the light of developments that have taken place since the last plenary meeting in Washington fourteen years ago.

At the first of these conferences the part played by the North of Scotland Hydro-Electric Board, in adding a relatively modest but nevertheless important contribution to the much needed additional power supplies in Great Britain, will doubtless be discussed —by that time the Board may well be able to report the commissioning of its first major station, which will add 130 MW to the ever increasing generating capacity in these Islands.

Last year's Convention considered the question of a 275 or 300 kV "backbone" grid to reinforce the existing 132 kV network, which would assist in bringing hydro power to the important centres of load, proposed in a paper by Mr. T. G. N. Haldane; but the scheme was to some extent unpopular with leading members of the British Electricity Authority's staff, who took part in the long and fascinating discussion that followed. In fact, a 275 kV grid line, primarily to give further opportunities for the study of high voltage problems, is now under construction in Great Britain. The British electrical industry (in subsequent papers) showed that it was capable of constructing cables, switchgear, and transformers for any practicable voltage, required either by the B.E.A. or other electricity authority in any part of the world. This year we shall watch with considerable interest those discussions which will take place under the chairmanship of Sir Vincent Z. de Ferranti, M.C., M.I.E.E.

The C.I.G.R.E. will hold its thirteenth session from June 29 to July 8, and its membership of some 1,500 highly responsible engineers will discuss no less than 120 papers dealing with generation, transformation, and rupturing of current; construction, insulation and maintenance of overhead and underground lines; operation, protection and interconnection of networks; and finally, higher voltages than those actually used, together with other subjects of general interest. Among the items of particular concern to hydro-electric engineers are those dealing with the transient impulse behaviour of alternators and their inherent impedance; progress in the development of power transmission by high voltage d.c. in Sweden; principles and applications of electrically operated water turbine governors; and many other papers dealing with those aspects of high voltage power system, construction, maintenance and operation, which apply particularly to hydro-electric practice.

Two days later (July 10) the Fourth World Power Conference opens in London. The International Committees of this Conference will open the proceedings by each giving a single report on energy resources and power developments, and here it may be expected that hydro-electric matters will be very much to the fore. The second division of the Conference is concerned with the preparation of fuels, while the third division deals with the production of power. Water power, including tidal power, has a place here, and discussion will even explore the possibility of abstracting power from water in the form of thermal energy derived from the sea.

In addition to the formal agenda and the prepared papers—and in some cases the prepared answers to discussions—which will be the concern of those attending the three important conferences, they will serve a much more valuable function. The bound volumes which, in due course, will issue from the various Secretariats will record the Proceedings, and there will be found in this storehouse of words, some

views that will advance the science of using the natural resources of the earth to aid mankind. But perhaps in the stimulation that one man receives from another, when he hears of a particular problem which has baffled him being solved on the other side of the earth, lies the truest and most lasting value of these technical discussions.

In a world where the steady acceleration in the rate of population growth is apparent in many quarters the only hope of survival without famine is in the greater and yet greater control of nature's bounty. Water Power has a contribution to make: irrigation coupled with hydro-electric generation can bring food and industrial prosperity in the end—but it is for the engineers to find the means.

Long-Term Planning Needed

WHEN drastic restrictions were imposed on the use of electricity the less responsible organs of the French Press came out with headlines, "*Les Coupures, Desastre National*," and asked for immediate plans for the construction of more steam power stations. Severe censures were heaped on the planning authorities for the failure of the electricity supply system; but those in a position to assess the situation from the technical angle did not, of course, share in the popular clamour.

The facts show that about half of the total power generated in France, and administered by *Electricite de France*, comes from hydro-electric plants in three main areas—the *Massif Centrale*, the Pyrenees, and the Alps. A plan was evolved immediately after the war for a very considerable reinforcement of the hydro-electric plants in all three areas, but the financial stringency from which France has suffered, in common with all other European nations in the post-war year, delayed the full development of the plan.

Three exceptionally dry years have followed in succession, and at no time have the reservoirs been able even to fulfil the long-term needs of existing power plants. Similar conditions have prevailed in Switzerland—where very much less than the French thermal plant is available—and in Italy; while deficiencies in hydro-electric output have also been reported in Spain and Portgugal.

Long-term statistical information, deployed in a manner that would be useful to the hydro-electric engineer, could have gone some way towards averting the present state of affairs—particularly in France—by providing firmer grounds for planning in past years.

This is not to suggest that the French engineers have not at all times used what information has been available; but the need is urgent for geophysical and climatological research to be pressed forward so that drought periods, even in the relatively distant future, can be more accurately forecast. Further, on the basis of such information it would be possible for storage facilities to be planned so that, even in a prolonged dry spell, the hydro-electric installations do not fail in their primary duty of supplying power.

Electrical Equipment for Europe

COMMENT on the European position relative to equipment for electric power stations is contained in a recent recovery report by the Organisation for European Economic Cooperation. All the O.E.E.C. countries, it is stated, believe they can overcome their own particular difficulties during the next few years in fuel and power as well as in manpower and materials. On special machinery for power stations the report records that " Western Europe can supply her own requirements in the field of electrical equipment provided orders are placed without delay and are grouped so as to permit a degree of mass production . . . In technique Europe is at least on a level with the rest of the world."

New Power Plant Commissioned

THE large-scale development undertaken by the British Columbia Electric Railway Company on the Bridge river advanced another stage recently when the third 62,000 h.p. generator was brought into commission. The first similar unit was commissioned at the Seton Lake plant in November, 1948 — nine months ahead of schedule—and the second in May of 1949.

The ultimate development of this station envisages a total capacity of 620,000 h.p. which will make it the largest in Canada, even when other projects now under consideration are completed, with the possible exception of the St. Lawrence River project.

Also from British Columbia comes news of the commissioning of a new 6,000 h.p. plant for the City of Nelson municipal station, and again the work has been carried out very rapidly.

Australian Projects

CONSTRUCTION of a hydro-electric power station of 42,500 kW minimum capacity at 50 p.c. load factor is included in a huge scheme of land development based on the Burdekin river in Central Queensland. The dam would be erected at a point about 100 miles from the mouth of the river. The scheme formulated by public works authorities in Queensland is now being studied by a Commonwealth Government technical committee.

Plant now on order for new hydro-electric stations in Tasmania has a combined capacity of 126,700 kW. In addition tenders have been called for a new station of 60,000 kW. These plants will bring the total installed capacity to 371,000 kW, compared with 104,500 kW in 1939.

Trade and Technical Press

A GREATER and more influential future for the trade and technical Press is implicit in the setting up of a joint consultative panel by the Anglo-American Council on Productivity and the Council of the Trade and Technical Press.

The panel will examine the circumstances in which the Press functions in respect of supplies of machinery and labour and the relations between itself and industry. It is not in doubt that a well-staffed and well-equipped trade and technical Press can render valuable service to industry in the pursuit of increasing efficiency and productivity, and that the relation

between the Press and industry should be that of ready cooperation.

On the one side it is suggested that the Press can offer to industry the means through advertisement of making known the character and range of its products and, through articles by competent and well-informed writers, of spreading knowledge of industrial techniques, processes and methods, and providing opportunities for the discussion of wide-ranging industrial problems from the scientific and technical to those of welfare and labour management. On the side of industry there is the opportunity to make known its achievements and researches by giving technical writers access to information and permitting its own experts to contribute suitable articles. It is recognised that the Press must equip itself adequately to fulfil this service to industry and that industry should appreciate and assist its endeavours to do so.

When the Anglo-American Council on Productivity met in the U.S.A. last year, it was given an insight into the effective part which the trade and technical Press of America takes in recording and stimulating industrial progress. The consultative panel will be assisted by the Economic Cooperation Administration in drawing further upon American experience.

Tamadi River (Japan) Development

THE American Westinghouse Electric Company has recently been undertaking a survey of the Tamadi river in Japan. The Ministry of Trade and Industry, through its Electric Power Bureau, is endeavouring to find capital for this large-scale development project, which is part of the five-year plan announced in May, 1948. It provides for ninety-three additional hydro-electric plants, developing (with the existing 1339 stations, many of which are small) a total power output of 37,920 million kWh a year.

Brazil—a Contract for Plant

IN AN ARTICLE on "Hydro-Electric Development in South America," published in the November-December issue, we stated that the Falls at Paulo Afonso on the Rio Sao Francisco in Brazil, were being developed. News now comes to hand that the Westinghouse Electric International Company has entered into a contract to supply the equipment for the first phase, which our Correspondent described as "a modest 120 megawatts of plant in relation to the ultimate development of 900 megawatts." The equipment is to be installed in the first of three power stations planned by the *Companhia Hidro-Electrica do Sao Francisco*, although many other river control works are envisaged in the final development of the valley.

Prospects in Venezuela

A DETAILED SURVEY of the Caroni river in Venezuela has been completed and a full report is expected to be issued soon. Earlier information showed that the potential yield was expected to be between 30,000 and 100,000 kW. The Caroni rises in South East Venezuela and flows into the Orinoco. Plans have been discussed for hydro-electric plants on the Chama and Uribante rivers and at Lake Maracaibo in North Western Venezuela. A 15,000 kW plant near San Felix and a 30,000 kW plant near Cristobal are also under consideration.

History of Engineering in Ipswich

THE IPSWICH ENGINEERING SOCIETY was formed fifty years ago "to enable engineers to meet and correspond and to facilitate the interchange of ideas respecting improvements in the various branches of engineering science and the publication and communication of information in such subjects." Since then the Society has gone from strength to strength, and to celebrate its jubilee an attractively bound book has been published giving a record not only of the activities of the Society and the personalities that have contributed to its success, but also of the firms that have made Ipswich a household word for engineering products in so many parts of the world. These firms engage some 10,000 workpeople and are represented by such names as Ransomes Sims & Jefferies Limited, E. R. & F. Turner Limited, Fisons Limited, Cocksedge & Co. Ltd., Ransomes & Rapier Limited, Reavell & Co. Ltd., The Manganese Bronze & Brass Co. Ltd., Crane Limited, Suffolk Iron Foundry (1920) Limited, Egerton (Ipswich) Limited and the British Steel Piling Co. Ltd.

British Council's New President

SIR HENRY DALE, O.M., has been elected president of the British Council in succession to Lord Riverdale, who has resigned for private reasons. Sir Henry Dale was a member of the Council's executive committee from 1943-1949, and chairman of its science advisory committee from 1942-1949. He has been President of the Royal Society, the British Association and the Royal College of Medicine, and shared the Nobel Prize for medicine in 1936. He is a member of, and has presided over, conferences of the Permanent International Commission on Biological Standards, and honours have been conferred on him by universities and learned societies of many Commonwealth and foreign countries.

Women to see Scottish Schemes

HYDRO-ELECTRIC schemes as such are not usually of first interest to women though the benefits flowing from them constitute an imporant factor in their lives. The Electrical Association for Women, during its jubilee conference at Perth in the first week of May, however, is to make arrangements for the 600 delegates from all parts of the country to visit and examine at first hand some of the schemes now in course of construction in Perthshire and the Highlands. The social and industrial significance of these and similar schemes will be the subject of a paper to be read by Sir Edward MacColl to the conference. The first branch of the association was formed in Glasgow in 1925; to-day there are more than 100.

General view of the penstock of l'Arvan (Alps)

Pressure Pipe Lines

French Engineering Practice described by
GEORGES FERRAND

Le dessin, la fabrication et le montage des conduites d'amenée aux stations génératrices ont suivi de très près les progrès de l'hydraulique en France. L'auteur étudie les problèmes de fabrication des conduites soudées et auto-frettées — ce dernier procédé permettant de réduire considérablement le poids des canalisations à très haute pression. Les différentes méthodes de frettage sont expliquées ainsi que leur influence sur le facteur sécurité de l'installation.

El diseño, construcción y montaje de las cañerías presión que alimentan las centrales generadoras de fuerza motriz han seguido muy de cerca los desarrollos de métodos prácticos hidráulicos en Francia. El autor discute los problemas relacionados con la manufactura de tubos soldados y de tipos con aros de refuerzo, los cuales contribuyen a una reducción de importancia considerable en el peso de los tubos descargando gran potencia a las centrales hidroeléctricas. Se explican los métodos para disponer los aros de refuerzo, junto con su influencia sobre el factor de seguridad de la instalación.

FRANCE has a great number of hydro-electric plants in her mountains—the Alps, Pyrenees and *Massif Central*—and on the larger rivers; they have earned for her engineers a well deserved fame.

The design, fabrication and erection of the pressure pipe lines (or penstocks) supplying the plants have followed closely the development of hydraulic practice. France has a number of installations showing considerable originality in this sphere.

This originality is shown more particularly in plants working under a high head and a large flow and therefore developing great power. This excludes installations of medium or low heads for which the designs developed in the past will become standard and generally accepted, although, of course, certain problems will always arise. Even in the case of a dam across the Rhone, where the problem is complicated by the fact that 100,000 h.p. generator sets operate under a very low head (about 100 metres), the design and fabrication of the penstock, although laborious, did not present particular difficulties compared with the magnitude of the undertaking.

On the other hand, when it comes to conveying to a power station a flow of 50 m3/sec under a head of 750 metres as at Malgovert (Savoie—France) or of 18 m3/sec under a head of 1,200 metres as at Pragneres (Pyrenees—France) all sorts of problems arise which will often considerably affect the whole of the installations, and consequently the cost of every kWh generated. Indeed, some of the installations now being constructed could not have been conceived if the methods of fabrication of pipes had not progressed so much in the last few decades. The Malgovert installation for instance will comprise two pressure pipes weighing together 4,500 tons for a plant capacity of 400,000 h.p.[1]. Twenty years ago the same installation would have necessitated 70 pipes side by side weighing together 25,000 tons. Such an undertaking would never have come into being. The engineer would have been content with four or five times less power and lower efficiency; alternatively he would have recommended a succession of installations of medium power. The latter solution is still often adopted in some countries, and the originality of French engineers lies in their daring to instal one single pipe for a very high head and large flow.

Electricite de France is at present investigating the construction of a plant of 600,000 h.p. with head of 1,220 metres and flow of 42 m3/sec; one single pipe would supply six sets of 100,000 h.p. each. The pipe would hold three times more power than the present record holding pressure pipe[2].

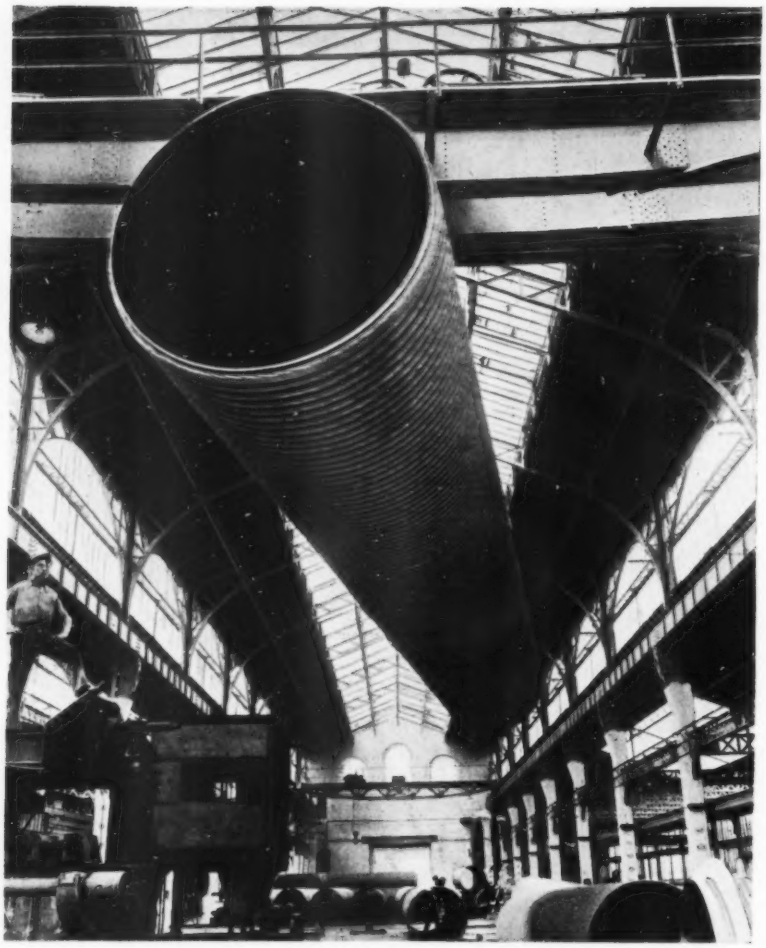
The advantages of a pipe carrying great power may still escape many engineers; thus we will consider a hypothetical problem—the design of a penstock for an installation with the following characteristics: head 1,000 metres; flow 20 m3/sec supplied by a regulating reservoir for 2,500 hours a year; length of the penstock 2,500 metres.

Figure 1 gives the mean economical diameter: 2.2m approximately; Fig. 2 gives the head loss: 11 mm per metre, and the water velocity: 5.20 m/sec.; the first figure gives a total of $0.011 \times 2{,}500 = 27.5$ m friction loss, or less than 3 per cent. of the head which is acceptable. A velocity of 5 to 6 m/sec is also quite acceptable in this class of pipe.

Pipe manufacturers, however, cannot make, by conventional methods, a pipe of this diameter and capable of withstanding a pressure of 1,000 metres (plus a pressure rise of about 15 per cent). It would mean a thickness of over 100 mm at the bottom taking a working stress of 11 Kg/mm2. The alternative would be to divide the penstock into a number of pipes; the limiting diameter being 800 mm, according to Fig. 2. The installation would require 14

(1) Head 750m., total flow 50 m3/sec., diameter of pipes 2.2 and 2.1m.

(2) The first installation of over 100,000 h.p. supplied by a single pipe is that of the BISSORTE built in 1932 with a head of 1,150m. and flow of 7.5 m3/sec. The power is 105,000 h.p. It is probable that if this development had been carried out today, taking into account improved practice, it would have been possible to make a pipe line carrying a greater power and contemplate the utilisation of a greater catchment. If, in addition, one takes into account the considerable reduction in the weight of pipes, it can be said that the cost per kW installed would have been reduced, everything else being equal. The penstock of the BISSORTE installation weighs 2,780 tons. This weight could have been halved by the use of methods perfected in the last few years.



pipes of this diameter in order to convey 20 m3/sec with the same friction loss as the single pipe. The pipe would weigh, according to Fig. 4, 320 Kg. per metre, or for the whole penstock:

$$14 \times 320 \times 2{,}500 = 11{,}200{,}000 \text{ Kg.}$$

Such a penstock would be out of the question.

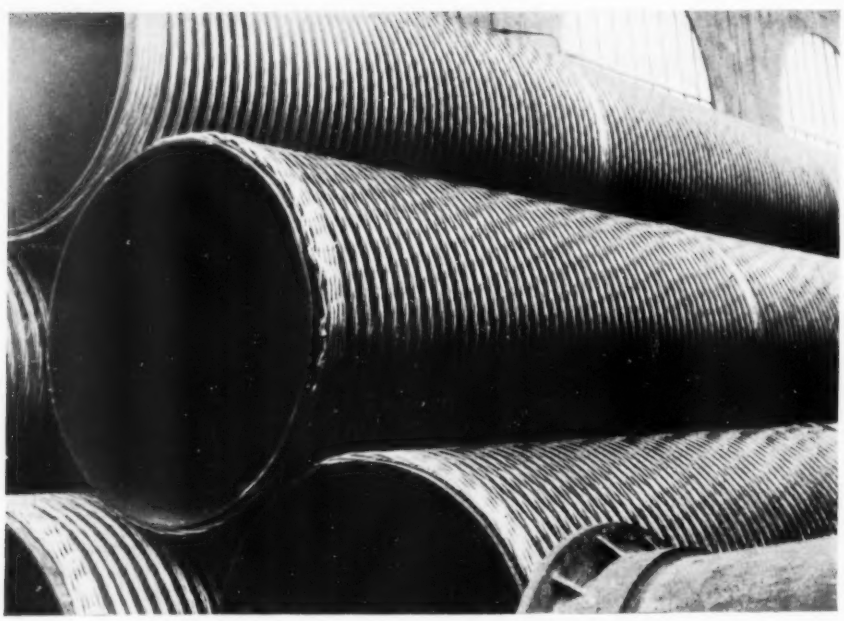
Thus it is necessary to go over the design and attempt to reduce the number of pipes by juggling with the friction losses, accepting greater losses in the lower portion of the penstock and compensating the increase by reducing the losses in the upper portion. For instance, taking 12 pipes of 800 mm in the lower half of the penstock it is necessary to adopt six pipes of 1,300 mm diameter in the upper half to keep the total friction loss at the same figure. The total weight of this penstock would be:

$$(6 \times 630 \times 1{,}250) + (12 \times 320 \times 1{,}250),$$

or a little more than 10,000,000 Kg. Probably a more detailed investigation on these lines would bring the weight down to 9 or $9\frac{1}{2}$ million Kg.

Referring now to the second curve of Fig. 3 it will be seen that it is possible to adopt,

Above: View of pipe-length: 12 metres, inside diameter 1.7 m



Right: Self-hooped pipes with helical winding; end bindings

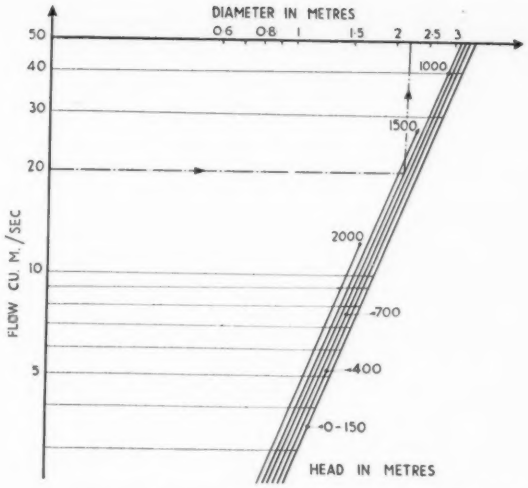
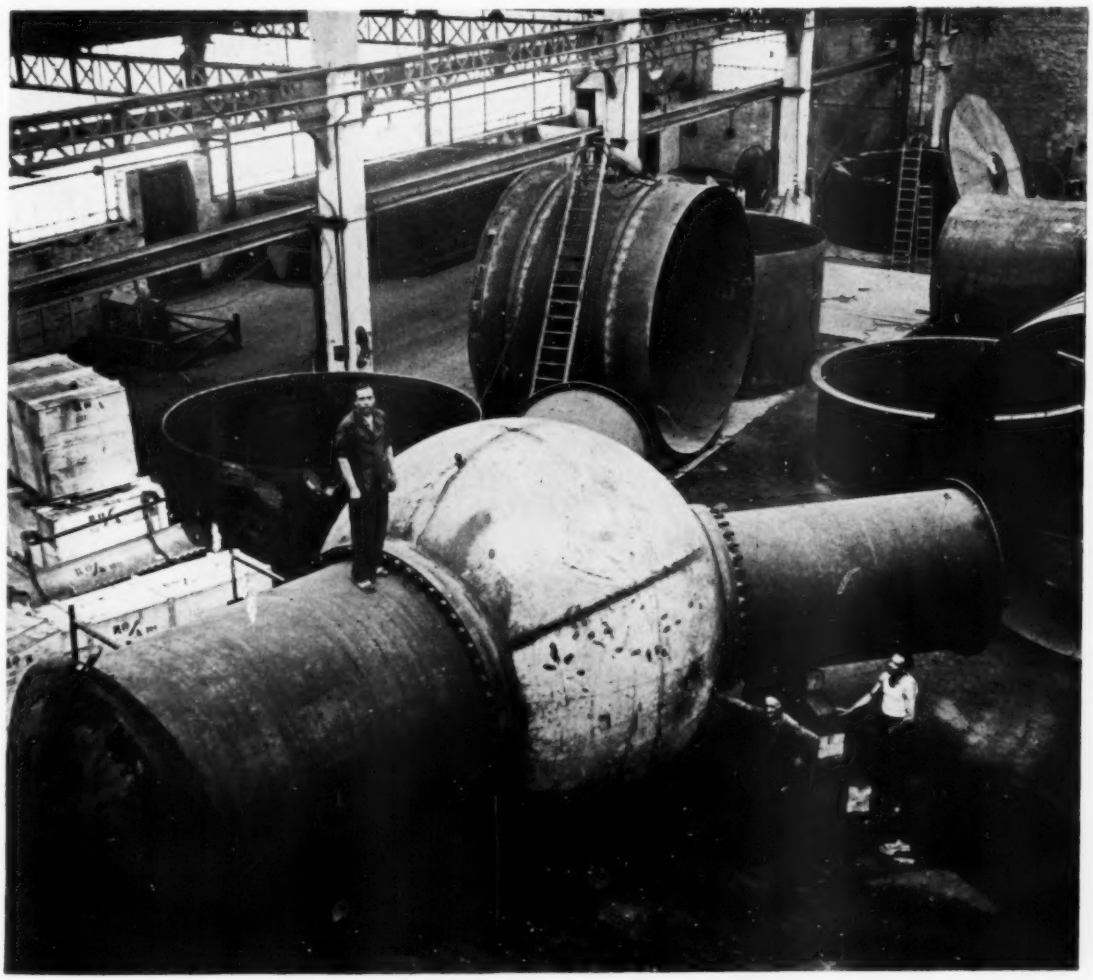


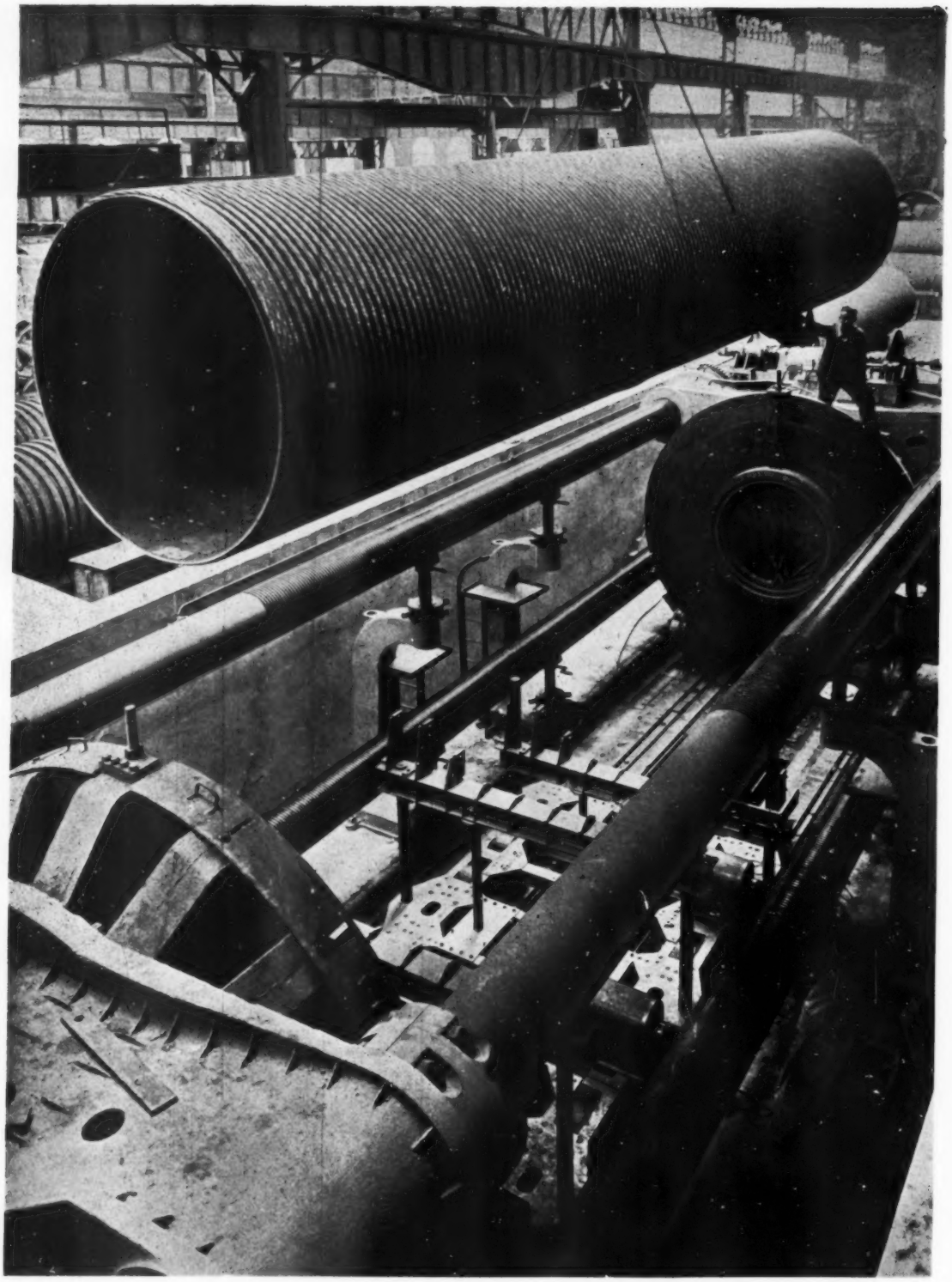
Fig. 1: Mean Economical diameter of a penstock for given flow and static head

Below: Testing between blank flanges of a Y piece. The pressure sphere is 4 m in diameter

under the same conditions, a penstock comprising a single self-hooped pipe of 2.2 m mean diameter. Such a proposal would, in fact, be well within the present possibilities of fabrication. The mean weight of such a pipe would be (according to Fig. 4) — taking H = 1,000 m and diameter = 2.2 m — 2,200 Kg. per metre, or for the whole length of 2,500 m: P = 5,500,000 Kg. The saving in weight over the previous example exceeds 40 per cent. In addition the cost of foundations and supports would be considerably reduced as indicated by Fig. 5. This graph shows for a diameter of 0.8 m a cost per metre of 1.9 units (or 19 units for 10 pipes side by side); for a single pipe of 2.2 m diameter it gives a cost of less than five units. The economy is considerable.

Generally speaking it is possible to count on a 15 per cent. reduction in cost whenever two pipes can be replaced by a single one. Moreover, if it is possible to introduce in the pipe line two sections of different diameters a further 5 per cent. can be saved; if three sections are used an additional 5.5 per cent. would be saved. This last figure shows, however, that it is not worth while introducing more than two sections on steep gradients because the saving is too small.





A pipe is placed between the face plates of a hydraulic press to be hooped by cold expansion of the shell and to be tested at double the maximum working pressure.—Power of the press 7,000 tons.—Maximum diameter admissible: 3 metres

Apart from other economies which can be effected by a thorough investigation of the problem, it is quite clear that the use of special pipes can lead to a startling reduction in the weight of the penstock.

The formula now used to give the thickness of a cylindrical skin of diameter D subjected to an internal pressure P is:

$$e = \frac{P D c}{2 E}$$

c being the selected factor of safety. This factor is always taken in France in relation to the elastic limit E. The specification brought out by the *Société Hydro-technique de France* lays down that under an internal pressure equal to 2.5 times the maximum working pressure in normal operation, the stresses shall not exceed the lower elastic limit.

Since the introduction, in the design of structures, of the notion of " fatigue limit " (approximating the elastic limit) engineers have known that in normal operation the stresses must always be less than this limit. It may be defined as the stress above which rupture will inevitably occur after a certain number of reversals of the stress and below which rupture will never occur. The factor of safety which used to be used was related to the ultimate strength; but it was abandoned many years ago in France.

Without going too much into the reasons why c is now always related to E, the following example may be of interest: take first a pipe designed with a safety factor of two in relation to E and of four in relation to R. Take then a pipe designed for the same conditions, with factors of safety of 2.5 in relation to E and three only in relation to R (ultimate strength). If, during operating conditions, an accidental stress occurs equal to double the design stress, what will happen? The first pipe will be subject to deformation, whereas the second will retain its initial shape. The second is obviously the better pipe although it has, in relation to rupture, a smaller factor of safety.

This notion may give rise to confusion particularly when it is applied to pressure pipes; these used to be manufactured from mild steel, rivetted or welded with water gas, and the metal was capable of " flowing " in the vicinity of the joints or welds and was thus able to absorb, without breaking, the concentrations of stresses at the discontinuities which could not be avoided. Things have changed now, electric welding having completely replaced the older methods and making possible a design entirely free of the previous defects.

The factor of safety having been defined, engineers have tried, by all possible means, to increase the component E in the above formula in order to reduce the thickness required for a pipe with given diameter and pressure. This will lead to a saving of steel and in many cases to a reduction in the number of pipes, for a large installation, when the thickness is the limiting factor.

The properties of weldable steels used in France progressed in the following manner : R = 35 with E = 20, then R = 48 with E = 28 and then R = 54 with E = 34 Kg/mm2. The permissible stresses also went from 8 to 11, and to 13.5 Kg/mm2. A method for improving the elastic limit of steel sheets was devised. The pipes manufactured on this principle are placed in a split mould with an internal diameter equal to the ultimate external diameter of the pipe after expansion, which can amount to 2, 3 or 4 per cent. The pipe is subjected to an internal hydraulic pressure which is gradually increased until the pipe is in contact with the mould, having gone beyond the elastic limit and acquired a permanent deformation. The permissible stress for a plate having been subjected to this treatment can reach 19 Kg/mm2 for normal working conditions.

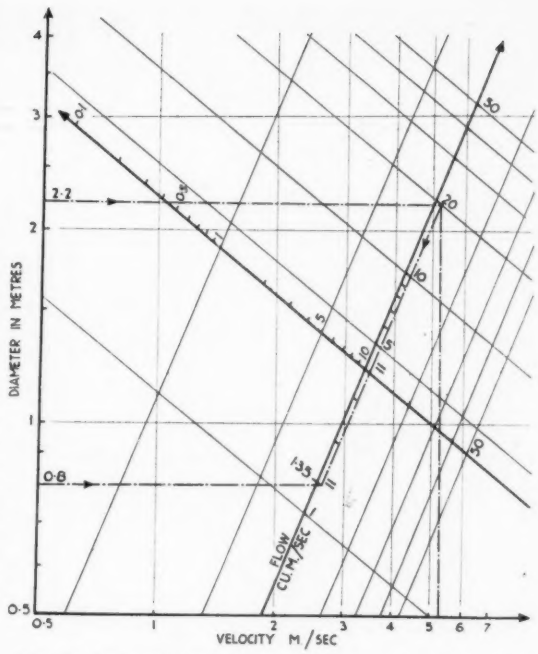


Fig. 2: Loss of head in penstocks for given diameter and flow

Similarly, attempts have been made for many years to reinforce the pipes forming the penstock with hoops stiffer than the plate and absorbing an important part of the stresses. The hoops are made from

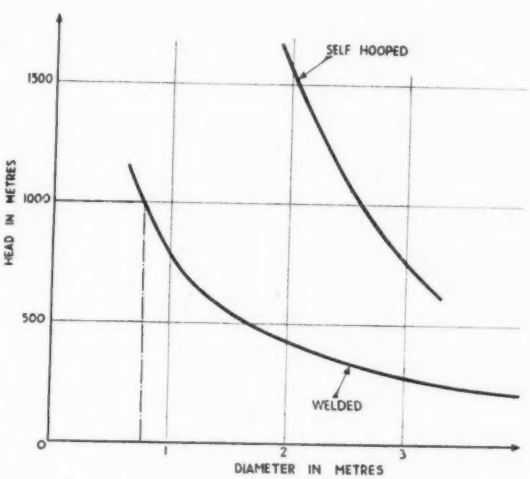


Fig. 3: Maximum diameter of self-hooped pipes compared with welded pipes

Anssois installation (Alps) under construction. Self-hooped pipes, plate thickness 15 mm. section of rolled steel hoop 80 × 43 mm; inside diameter 1.600 mm, test pressure 195 Kg/cm2

a steel having an elastic limit much higher than that of even the latest weldable steel of high elastic limit. One of the main difficulties which used to limit the use of hoops made of processed steel was the fact that they had to be placed at low temperature in order to preserve all the properties of the steel. The problem was solved by the method called "*auto-frettage*" (self-hooping), consisting of placing the hoops, without heat, and expanding the pipe walls.

The pipe is made with an external diameter such that the hoops can be placed, cold, without difficulty. When they are placed and properly spaced, the whole pipe is placed between the plates of a hydraulic press. The internal pressure is raised until the hoops are considerably stretched over the pipe walls which have acquired a permanent deformation. The hoops are designed in accordance with the requirements of the society's specification, namely that under a pressure equal to 2.5 times the normal working pressure, the lower elastic limit is not exceeded. This limit is, for rolled steel hoops, from 60 to 105 Kg/mm2 depending on the quality of steel used.

A more recent method allows the use of hoops having an elastic limit of 150 Kg/mm2. In this case, cabled wires with a tensile strength of 200 Kg/mm2 are used instead of rolled steel hoops. These cables are placed on the pipes either as separate rings similar to the hoops, or as helically wound cable tied at the ends of the pipe. In either case the cable is placed without initial tension, which is essential to ensure that the stresses produced by the internal pressure will equal the values calculated by the formula applicable

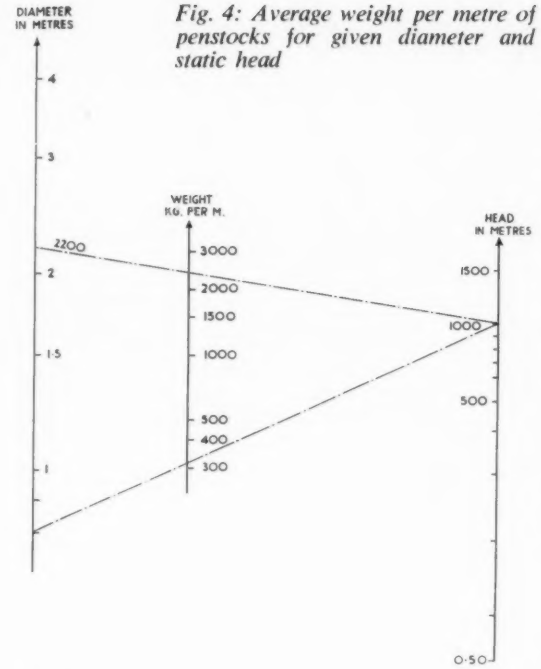


Fig. 4: Average weight per metre of penstocks for given diameter and static head

to self-hooping.

Self-hooping enables the engineer to select any desired distribution of the stresses between the pipe walls and the hoops. Over the whole length of a pressure pipe in which the pressure varies continuously it is possible to vary only one of the two structural elements; either the thickness of the pipe walls or the section (thickness × width) or spacing of the hoops. In this way a pipeline can be made of the same thickness and with the same size of cable over a considerable length, only the pitch of winding being varied; this is a great convenience in fabrication.

Although the methods already described have resulted in a considerable reduction in the weight of pipe lines conveying water to power stations, their main virtue is the fact that they allow the fabrication of pipes carrying much greater power with the same equipment as before. This is possible as the wall thickness of a self-hooped pipe is generally of the order of one-quarter to one-fifth of that of a conventional welded pipe.

It is, of course, necessary to have means for testing the pipes in the shop, and French industry has at its disposal a hydraulic press of more than 7,000 tons, which allows the successful manufacture of pressure pipes carrying great power.

Acknowledgment

The graphs reproduced in this article were prepared by *Electricite de France*. They give very approximate indications which are only valid for preliminary studies intended in the roughing out of the problem.

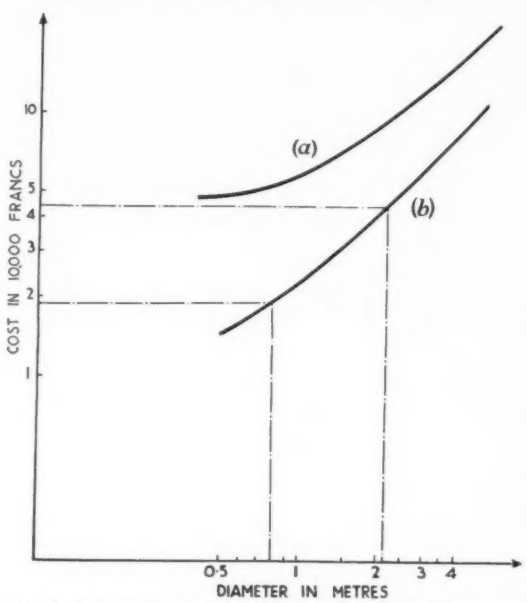


Fig. 5: Average price per metre of the substructure of welded pipes—a, buried; b, above ground—Unit cost = 10,000 frcs. as on January 1, 1949

Courses for Specialists from Overseas

The British Council course on "New Hydro-Electric Developments in the Highlands of Scotland" held last year was so successful that a similar one is to be included in the 1950 programme.

Some 15 qualified engineers and regional planners from oversea whose work gives them a special interest in the development of hydro-electricity will spend the period from June 7 to 22 inspecting hydro-electric schemes at different stages of development—each adapted to meet special needs and special conditions —and also visiting manufacturers of hydro-electric machinery.

The itinerary has been drawn up in consultation with officials of the North of Scotland Hydro-Electric Board, and engineers at each site will conduct the party round and explain the technical problems involved.

Correspondence

MULTIPLE ARCH DAM

To the Editor of WATER POWER

Sir,

I have been advised that there is being built in Europe, possibly Austria, a multiple arch dam. As I have not been able to obtain any details of such a dam, it would be greatly appreciated if your readers could advise me of it and of its location, or any other multiple arch dam in Europe or North Africa which may be under construction at the present time.

My interest in such matters is on account of the fact that in the near future this Commission will be commencing, in connection with the Kiewa Hydro-Electric Scheme, the construction of such a dam.

Yours faithfully,

ALEX. J. POPPINS,
Plant Engineer.

State Electricity Commission of Victoria,
475, Oxford Street, (2nd floor),
London, W.1.

Hydro-Electric Development in India

By H. A. SIEVEKING, M.Sc., M.Inst.C.E., M.I.E.E.

An authoritative account of the country's resources

Cette étude du potentiel hydro-électrique de l'Inde est basée sur l'information fournie par M. A. N. Khosla, ingénieur-conseil du Gouvernement de Dehli. Le pays a été divisé en six zones, et l'auteur examine les différents projets qui seront étudiés et probablement mis en chantier vers 1956, et que l'on peut s'attendre à voir achever aux environs de 1960. Les installations hydrauliques dont la mise en service est prévue pour 1953 environ, et ceux des projets qui doivent être achevés entre 1953 et 1956 sont indiqués en détail sous forme de tableau.

Una revista de las muy variadas posibilidades hidroeléctricas de la India, basada sobre las informaciones facilitadas por Mr. A. N. Khosla, ingeniero consultante del Gobierno de la India. El país ha sido dividido en seis regiones y se discuten los diversos proyectos que probablemente serán estudiados y adelantados en el año 1956, y que puede esperarse que serán completados a eso de 1960. Los pedidos para las instalaciones hidráulicas serán transmitidos a eso de 1953 y los proyectos que se espera serán puestos a la práctica durante el período de 1953-1956 están detallados en forma tabular.

IN 1946 there was set up in India a body which is now known as the Central Water Power Irrigation and Navigation Commission (abbreviated to C.W.I.N.C.). This body is charged with the duty of "initiating, co-ordinating and progressing schemes of control regulation and utilisation of water hydro-electric power and waterways in the country in consultation with the Provincial and State Governments."

In 1941, the Electrical Commissioner's Office was set up, primarily to control public electricity supply in wartime. In peacetime functions developed into a statistical agency for the whole electric public utility industry in the country, the department of the Government concerned with drawing up new legislation for public electricity supply, a Central Information Bureau and an advisory body to assist in the co-ordination of electricity development. In 1945, the Central Technical Power Board was formed with responsibilities closely similar to those of C.W.I.N.C. but in the electricity supply field. It was mainly intended to plan large power projects. C.W.I.N.C. has now taken over the hydraulic planning work previously done by the Central Technical Power Board, while the latter has been merged with the Electrical Commissioner's Office to form what is now known as the Central Electricity Commission.

The year 1947-48 showed a deficit in India's food production of about 2.8 million tons at a time when her population was estimated at 342 million; by 1960 it is estimated that the population will have risen to 395 million and that during the period 1948-1960 there will be a food deficit of some 10 million tons to be made up. The only way in which India can become self-supporting is by increased food cultivation and therefore by increased irrigation.

To one who, like the writer, has flown hundreds of miles over northern India the vast network of irrigation canals that are visible is an impressive sight, yet on the above showing they must be greatly increased if dependence on external food supplies, particularly from the dollar areas, is to be avoided. Here then is the first great justification for the new body.

At the present time India has installed in its Public Supply Stations about 800,000 kW of steam and 550,000 of hydro-electric plant and produces about 5,000 m. kWh equivalent to roughly 14½ kWh per capita. From any point of view this consumption is extremely low and the coming years must show a great increase in installed generating capacity and output of electricity.

The Indian coal fields lie mainly on a line running west out of Bengal into Behar and then south to the borders of Orissa. It is at present estimated that if the existing rate of consumptiin is maintained the coal resources will be exhausted in one hundred years. With her large and widespread potentialities for hydro-electric development is is natural that in India much attention should be in process of being paid to the best method for initiating suitable schemes. As a first step the country has been divided into six main areas, as shown in the map, Figure 1. These areas follow certain physical characteristice of the country, namely:

AREA 1.—The western Ghats. A range of hills running close to the western coast of the peninsular, providing means for comparatively high-head development.

AREA 2.—The hill country of Kashmir, including the western Himalayas and the headwaters of the Indus—an area suitable for high-head plants.

AREA 3.—The territory covering the gentler eastern slopes of the Ghats of Area 1, in the south, and including the level country drained by the Mahanadi River in the north. A stretch of land covering high head developments near the source of the eastwards flowing rivers in the south and ranging down to combined flood control, irrigation and low head power developments along the Mahanadi and Godaveni valleys.

AREA 4.—The vast flat plains drained and irrigated by the Ganges and Jumna. Territories that seem at first so unpromising for hydro-elecrtic development but which are already dotted with a number of low-head stations placed at suitable points along the irrigation canals, making use of several canal falls and generally operating under heads of 60 ft. or less. This area also includes the

Himalayan foothills on the borders of Nepal where certain high-head developments are also possible.

AREA 5.—The eastern end of the Himalayan range, including the headwaters of the Brahmaputra, is a territory that has great potentialities but is so far removed from centres of population that initiation of schemes here is likely to be postponed for many years.

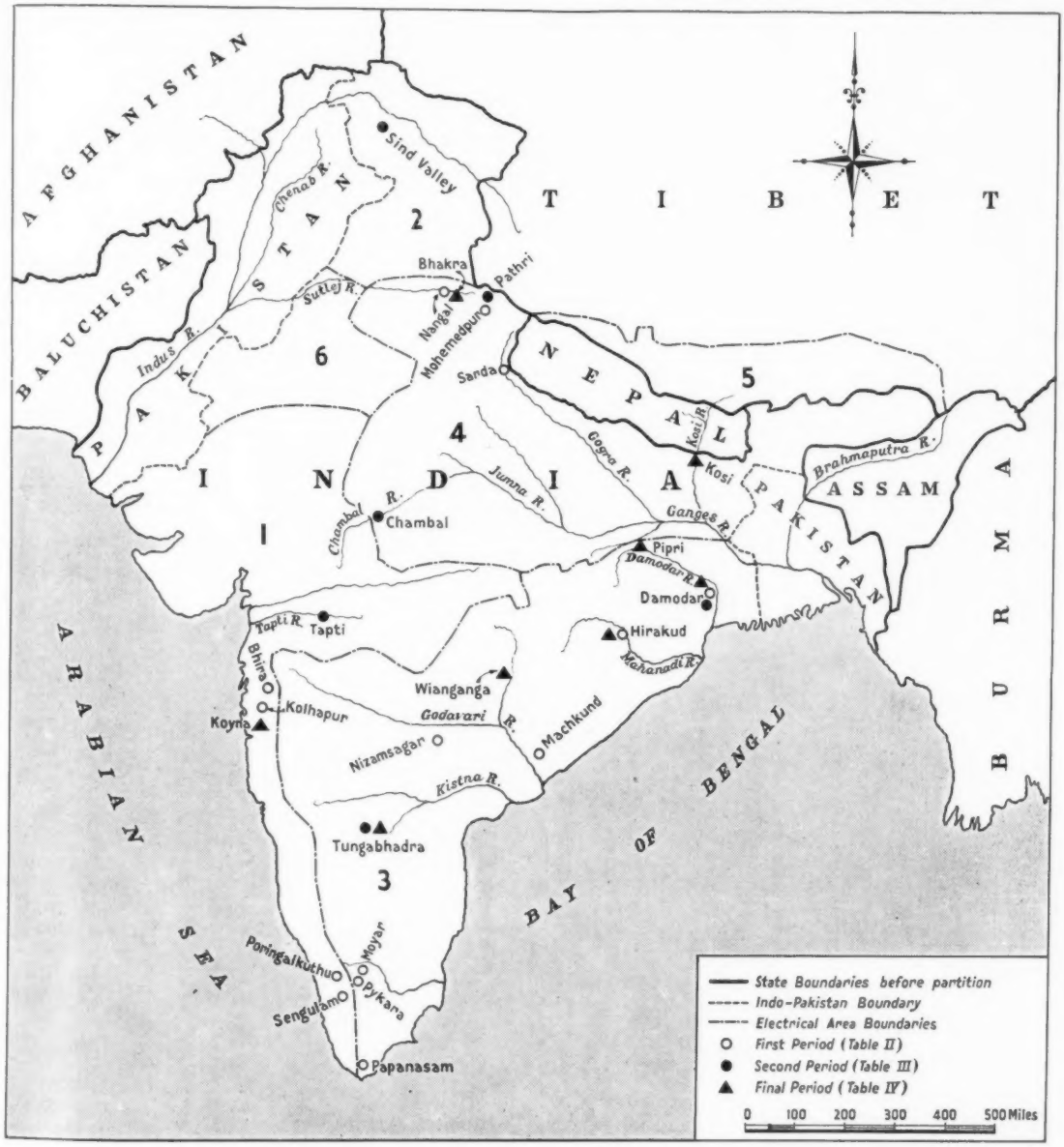
AREA 6.—The desert lands of eastern Sind and northern Rajputana offer no prospect of further development.

Since 1946 C.W.I.N.C. have surveyed the above territories and outlined a programme of development for the next decade and hope, by the end of the period, to have increased the installed hydro capacity very considerably. For a full appreciation of the position that hydro-electric plant occupies in India a brief review of the whole electricity situation seems desirable.

Fig. 2 shows, for a ten year period, the total generating plant installed in supply authority stations together with the associated annual maximum demand, also the division of the installed plant between hydro, steam and diesel stations.

Similarly Fig. 3 shows, for the same period, the total number of kilowatt hours generated annually and the generation for each type of prime mover. The following facts emerge from these graphs: (1) The part played by diesels, though important in itself, is negligible in the overall picture. (2) That the amount of spare plant, that is the difference between the M.D.

Fig. 1: Hydro-electric sketch map of India



and the installed capacity, is decreasing steadily but is still of the order of 45 per cent. (3) Although hydro and steam represent some 57 and 36 per cent. respectively of the installed capacity today, the relative proportion of units generated is 46 and 52 per cent. Actually the M.Ds. on the two types of prime mover are very nearly 44 and 50 per cent. of the total M.D. so that the steam stations are carrying the bulk of the spare plant. (4) The installed capacity of the steam stations has risen by 45 per cent. over the ten years whereas that of the hydro stations has only risen by 25 per cent.

Turning now to the availability of supply, it will be found that out of 562,000 townships having a population of 10,000 or less, only 2,000 have electricity available though nearly 600 of the 1,000 or so of the larger towns are receiving an electricity supply.

The proportionate division of the kilowatt hours sold in 1948 between the major users is shown in Table I., the corresponding figures being given for 1939. Essentially the proportionate division remains the same except that the domestic utilisation has increased at the expense of the railway load.

During the period under review the increase in total consumption was 83 per cent., but that of domestic consumers was 150 per cent. The most notable increase in the residential consumption, however, took place between 1944 and 1948 during which it practically doubled, the consumption per consumer rising to over 400 units p.a. Nevertheless the domestic consumption per head of population is still less than 1¼ units.

On the industrial side the number of units purchased from public supply is approximately 2½ million or about 7½ per head. A further 1¼ million units were generated by industrial private plants. Possibly the iron and steel industry generation of roundly 0.4 million kWh may be transferred at some date to Public Supply but the remaining industries such as textiles, sugar, paper, cement and collieries, from the nature of their processes or product, are most unlikely to transfer a greater portion of their load to the local Supply Authority.

Where then does the future load appear likely to arise? There is first the large untapped domestic field. Here the development must be twofold. Increased electrification of those towns and cities already having electricity available and the provision of supplies to many more of the localities now without supply. In the former case the question is primarily one of increased urban distribution capacity. The latter is more complex, and the question arises as to whether it be more economical to increase the high-tension

TABLE I.
Per cent. Division of Units Sold into Types of Load for Years 1939 and 1948

Type of Load	1939	1948
Commercial - -	6.7	7.7
Irrigation - - -	8.3	8
Domestic - - -	8	11
Traction - - -	11	8
Industrial - - -	66	65.3
Totals % - - -	100	100
Million kWh - -	2,033	3,721

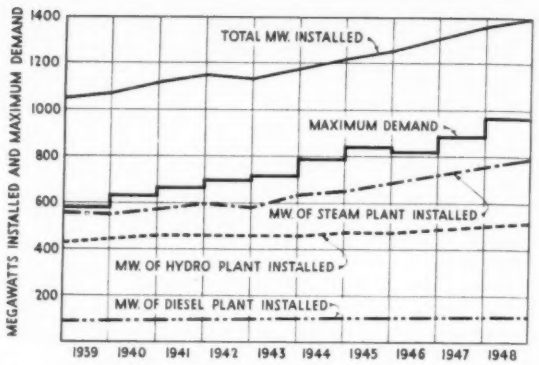


Fig. 2: Plant installed and annual max. demand: 1939-48

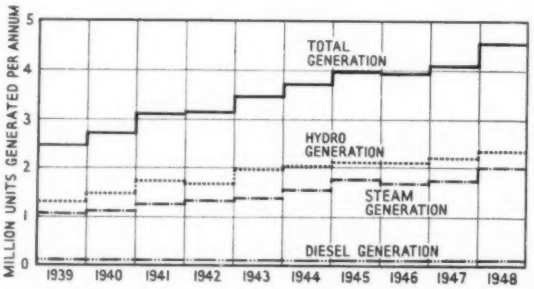


Fig. 3: kW generated per annum; 1939-48

network (there are only 1,500 circuit miles of line at voltages of 100 kV and over) or to install many more diesel stations, of which there are already 254 with an average installed capacity of 420 kW, an average M.D. of one half this, and an average annual output of a mere 600,000 kWh. If industrial development stagnated then the diesel solution might be the more economical but this premise is obviously false —industry will not stagnate and the heavy loads associated therewith will necessitate the development of widely scattered hydro-electric sites and will undoubtedly permit of economic high-tension supplies being made available for hundreds of smaller remote townships.

The most vital question is, therefore: Is there a probability of an appreciable increase in industrial load? The answer is certainly, yes. The subject is a complex one and has been reviewed by the former Government Planning and Development Department under the late Sir Ardeshir Dalal. From the work carried out by, or at the instigation of, this Department, the following seem to be the probable industries in which early development or initiation can be expected: ferro alloys; electro-chemicals; aluminium production; iron and steel; together with a large number of other industries which, individually, are smaller consumers of electricity. Within the scope of this article it is not possible to assess, even roughly, the probable magnitude of the demand on the Public Supply systems of the country in the next decade but an indication will now be given of the lines along which it is intended to develop. It has already been shown that, as far as possible, it is desirable to concentrate on hydro-electric development rather than increase the consumption of coal and, even more so, of diesel oil.

TABLE II.

Hydro Plant Due for Commissioning by about 1953

Plant	Province or State	Area No.	MW Installed	Remarks
Damodar Valley Corporation	W. Bengal	3	6	3 Francis turbines
Kolhapur	Bombay	1	4	3 Kaplan turbines
Bhira	Bombay	1	22	1 Impulse turbine
Moyar	Madras	3	12	1 Vertical impulse turbine
Pykara	Madras	3	13	1 Francis turbine
Papanasam	Madras	3	10	1 Francis turbine
Machkund	Madras	3	35	2 Francis turbines
Hirakud	Orissa	3	125	2 stations; 2 Kaplan turbines in each
Nangal	E. Punjab	4	96	2 stations; 2 Kaplan turbines in each
Sarda	U. Provinces	4	41	3 Kaplan turbines
Mohemedpur	U. Provinces	4	9	3 Kaplan turbines
Nizamsagar	Hyderabad	3	10	3 Kaplan turbines
Poringalkuthu	United Travancore	1	16	2 Francis turbines
Sengulam	and Cochin	1	50	4 Impulse turbines
Total	—	—	449	20 Kaplan turbines *(285 MW)* 9 Francis turbines *(80 MW)* 6 Impulse turbines *(84 MW)*

It must always be recollected that for every £1 spent on electrical development £10 is spent on industrialisation.

In formulating their programme, C.W.I.N.C. were naturally guided by the very prosperous condition of India during and immediately following the late war. They envisaged an increase in hydro-electric capacity installed of some 8 million kW over the seven year period 1949-1956. Unfortunately, India has suffered a recession and this capacity will probably not become available because of financial difficulties and lack of load. The total expenditure over the seven years was estimated at £400 million of which £90 million was estimated to be for external expenditure and the remainder internal. The 1949 Budget allowed for a grand total expenditure of £240 million so that the mean annual expenditure on C.W.I.N.C. proposals represents roughly a 25 per cent. increase in the Budget expenditure, a situation that could, unfortunately, not be tolerated.

We can make some assessment of the situation by considering: (a) What plant has actually been ordered and is likely to come into service in the next three years. (b) What schemes are at the moment being actively pursued and are likely to be put in hand during the next three years for coming into service by, say, 1956. (c) What schemes are likely to be studied and proceeded with between now and 1956 and which can be expected to be completed by about 1960.

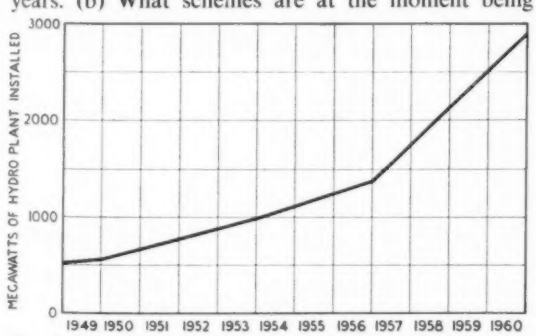


Fig. 4: Possible H.E. installation increase during next 11 years

A graphical review under the above headings is shown in Fig. 4, each heading is treated separately in Tables II., III., IV., which summarise the principal data; finally Table V. gives the trend over the next ten years for each area and the probable numbers and gross capacity of each type of turbine to be installed. The most striking feature of Table V. is the very large number of Kaplan turbines relative to the total number of units, namely 52 ranging from the 45 MW sets proposed for Wainganga to the 1.3 MW turbines at present being installed at Kolhapur. The Francis reaction group is remarkable for the comparatively large capacities of the individual machines (45 MW average) culminating in the 200 MW sets that are contemplated at Kosi. The impulse group brings out the fact that India has already largely developed her high-head installations which are situated mainly in Area 1 along the Western Ghats, and that future development will be mainly concentrated on medium and low head falls.

It may be of interest, in conclusion, to give some brief notes on a few of the larger schemes. The following notes treat of the projects that are interesting from the hydro-electric aspect and do not necessarily refer to schemes that are to be developed immediately.

KOSI: This scheme, Fig. 5, is the most interesting that exists in India today. As at present envisaged, a dam some 750 ft. high will be built across the Kosi, at the Chatra Gorge, about 150 miles above its junction with the Ganges. As the map shows, the resulting artificial lake will consist of an east-west branch roughly 30 miles long, and two spurs, running nearly due north, respectively 20 miles and 15 miles in length. The total surface area will be of the order

TABLE III.

Hydro Plant Likely to be Commissioned between 1953 and 1956

Scheme	Province or State	Area No.	MW Installed	Remarks
Damodar Valley Corporation	W. Bengal -	3	100	1 station with 1 × 20 MW Francis turbine 2 Stations with total of 4 Kaplan turbines totalling 80 MW
Tapti River - -	Bombay - -	1	50	2 Francis turbines
Tungabhadra - -	Hyderabad	3	15	4 Kaplan turbines
Sind Valley - -	Kashmir - -	2	5	2 Horizontal Francis turbines
Tungabhadra - -	Madras - -	3	30	4 Kaplan turbines
Chambal River - -	Rajasthan -	4	150	3 Francis turbines
Pathri - - -	U. Provinces -	4	20	3 Kaplan turbines
TOTAL - - -	—	—	370	15 Kaplan turbines *(145 MW)* 8 Francis turbines *(225 MW)*

TABLE IV.

Hydro Plant that may be Commissioned between 1956 and 1960

Scheme	Province or State	Area No.	MW Installed	Remarks
Damodar Valley Corporation	W. Bengal -	3	100	4 stations with total of 5 Kaplan turbines totalling 50 MW 2 stations with total of 3 Francis turbines totalling 50 MW
Kosi River - - -	Bihar—Nepal -	5	600	1 station with Francis turbines (3 sets)
Koyna River - -	Bombay - -	1	125	2 Impulse turbines
Wianganga - - -	Central Provinces	4	180	4 Kaplan turbines
Tungabhadra - -	Madras - -	3	30	4 Kaplan turbines
Hirakud - - -	Orissa - -	3	125	2 stations, 2 Kaplan turbines in each
Bhakra - - -	Punjab (E) -	4	160	4 Francis turbines
Pipri - - - -	U. Provinces -	4	210	3 Francis turbines
TOTAL - - -	—	—	1,530	17 Kaplan turbines *(385 MW)* 13 Francis turbines *(1,020 MW)* 2 Impulse turbines *(125 MW)*

TABLE V.

Summary of Present and Future H.E. Installations by Areas

Area No.	Mill kW at present installed	Mill kW installed. 1950—53	Mill kW installed. 1953—56	Mill kW possible installation 1956—60	Total Mill kW
1	0.250	0.092	0.050	0.125	0.517
2	0.025	—	0.005	—	0.030
3	0.171	0.211	0.145	0.255	0.782
4	0.050	0.146	0.170	0.550	0.916
5	—	—		0.600	0.600
6	0.050	—	—	—	0.050
Total -	0.546	0.449	0.370	1.530	2.895
Cumulating Total -	0.546	0.995	1.365	2.895	2.895

Future Installations by Turbine Types:

Kaplan: 52 Units of a total capacity of 815 M.W. *Francis:* 30 Units of a total capacity of 1,325 M.W. *Impulse:* 8 Units of a total capacity of 209 M.W.

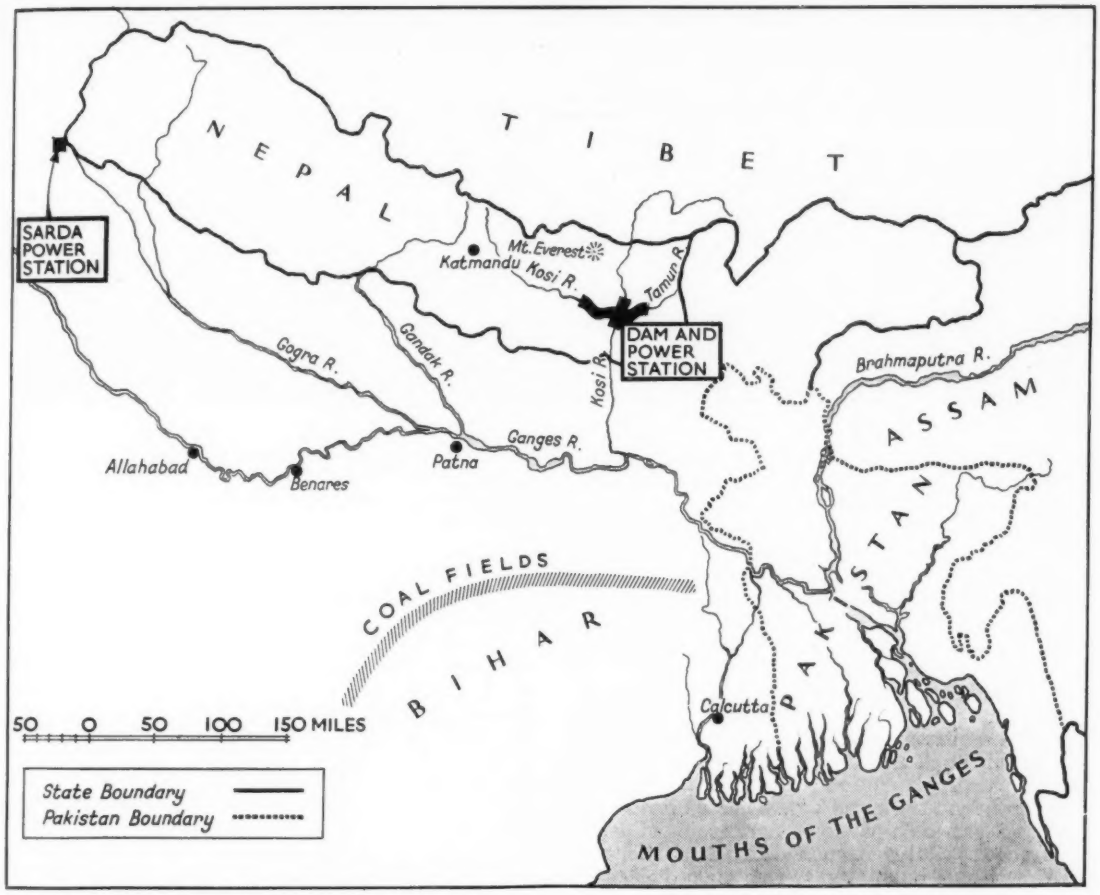


Fig. 5: Map of the Kosi scheme

of 200 square miles and the effective volume is expected to be 11 million acre feet.

The curious shape of the lake is due to the site being located in the Nepalese Himalayan mountains where narrow valleys are formed by the spurs running off the main Himalayan range. Mount Everest lies 60 miles due north, and the capital of Nepal, Katmandu, lies 100 miles to the north west, while only a short distance away is the sacred Baraha Kshetra temple. It is intended to use the impounded waters to irrigate a million acres of Nepalese lands and two million acres in Bihar. In addition flood control of the Kosi will help to reduce the flooding of the Ganges and, of course, soil conservation and silt control as well as malaria prevention will be important incidental benefits.

From a power production point of view it is estimated that the site can develop up to 1.8 million kW under a head of roundly 550 ft. This is the same amount of power as will ultimately be generated at Grand Coulee in the U.S.A., though the head at Kosi is more nearly that obtained at the Boulder Dam. The Boulder sets are 80 MW each. At Kosi the possibilities of 200 MW sets are being investigated. Generator design will limit the speed of such a set to about 125 r.p.m., so the turbine runner would be about 23 ft. maximum diameter, 10 ft. high and weigh over 60 tons. Enough has been said to show that to transport such a runner from a railhead such as Bhagalpur, through Nepal, by mountain road to site would be difficult. Even if the runner were split, not a desirable thing, though it has been done elsewhere, the problem would still be great. The generator, too, would present many transport difficulties but here considerably greater subdivision is possible. The shaft would also be difficult to handle, though not so heavy. Probably it will be found, when investigations have been carried further, that 100 MW sets as a maximum will be the most economical both as regards transport and spare capacity for the system. On present day prices it is suggested that the cost of the hydro-electric portion of the scheme will be of the order of £70 million, a very heavy financial outlay.

A vital, and up to now not wholly solved, problem is where to utilise the available power. No one question the need for power but the load centres such as Calcutta, the coal belt, and the smaller cities such as Patna are all up to 300 miles distant from the site and thus the transmission of 1.8 million kW of power over such a distance requires exceptionally close investigation to see to what extent it is actually possible.

DAMODAR VALLEY CORPORATION: The Corporation is a semi-autonomous body which was

Fig. 6: The dam at the entrance to the Sarda Canal

set up by statute about eighteen months ago and is charged with very wide responsibilities in the catchment area of the Damodar River. More particularly, it is to undertake a multi-purpose development covering flood control, electric power generation and transmission and irrigation. The Damodar has a bad record having caused untold damage and taken toll of many thousands of lives within living memory. Its estimated flood peak approaches a million cusecs and the scheme for its control comprises seven dual purpose dams and an irrigation barrage in the lower reaches at Durgapur. The latter would command some three-quarter million acres of perennial irrigation within 50 miles of the Calcutta area where about six million people require to be fed. It is estimated that the fully coordinated development of the catchment will provide a power system capable of dealing with an electrical maximum demand of about 300 MWs. and that in an average year about half of this would be derived from the hydro-electric installations, the remainder being derived from steam plant.

The catchment, which approximates to 8,500 square miles, lies in an area of great industrial promise for the future, being heavily endowed with high grade mineral resources in the shape of coal, iron ore, bauxite and limestone.

BHAKRA-NANGAL: At Nangal a low dam is to be built across the Sutlej forming a large lake. From here a canal will feed two power stations, respectively about 12 and 18 miles away, at each of which a fall of 98 ft. will be available. Two Kaplan turbines of 24 MW each are to be installed at each station. Some 18 miles above the weir, at Bhakra, a 480 ft. high dam is to be built across a gorge in the Sutlej. The resulting effective storage will amount to $3\frac{1}{2}$ million acre feet for irrigation and power. It is expected that two power stations will ultimately be built at the foot of the dam each capable of producing around 100,000 kW. Among other features of interest is the fact that, owing to the restricted space, one station will be underground—the first of this type to be proposed in India.

A complete model of the scheme has been prepared and the highly suitable site for the dam is clear from this. A fairly considerable amount of road making will also be required. Further, the regulated flow from the upper reaches will allow the installed capacity in the Nangal stations to be doubled. Work on the first stage of Nangal is under way and much of the preliminary work for Bhakra has been completed.

MAHANADI VALLEY: This river, which is in Orissa, has three suitable sites for power development. The first of these, near Sambalpur, is now under active construction. Here two stations four miles apart and with heads respectively of 76 ft. and 88 ft. are to be built, each housing two Kaplan turbines of 25 MW each for the low-head plant and 37.5 MW each for the higher head. The peculiar interest of this scheme is, however, not its engineering aspects but the fact that it is the first large scheme to be undertaken departmentally by C.W.I.N.C. After only twelve months work on site the progress is truly remarkable, a bridge for rail and road traffic 3,000 ft. long having been completed, 24 miles of roads, a township housing 6,000, workshops and repair shops and a diesel power station; in addition work has been done on the two dams. When it is recollected that for four months out of the twelve work is retarded by the monsoons and that the whole of the labour is trained from "green," it is a truly remarkable achievement and will be watched with satisfaction by all interested in the future of India.

It will no doubt be said by many that India's hydro-electric development will be retarded by lack of suitably trained personnel. This is realised and among other recommendations made by the Economy Committee is one that reads: "The Central Government should constitute in consultation with the Provincial Governments an All India Service of Irrigation and Hydro-Electric Engineers."

Steps are now being taken by C.W.I.N.C. towards this and, of course, the active cooperation of the Universities such as Benares, Roorkee, Bangalore and others is evident. The desire that so many students show to enter this service, when properly qualified, is most encouraging. It is also pleasing to note that C.W.I.N.C. have a hydraulic research station at Khadakvashla, near Poona, where all types of hydraulic problems are studied.

Sincere thanks are due to Mr. A. N. Khosla, Chairman of C.W.I.N.C., Consulting Engineer and Additional Secretary to Government, by whose sympathetic cooperation the information published in this article has been made available.

Geological Surveying

By J. E. RICHEY, Consulting Geologist, Edinburgh. An exposition of the work entailed and some examples of its application in the investigation of water power schemes.

Un exposé des travaux que comporte l'expertise géologique et divers exemples de son application à l'étude des projets hydro-électriques. Chaque élément d'observation, déclare l'auteur, qui est un expert-géologue, doit trouver sa place dans les diverses interprétations du thème géologique. Des théories sont construites et rejetées à la lumière de constatations nouvelles jusqu'à ce que, ses travaux terminés, le géologue soit à même de donner ses conclusions. Il est nécessaire que l'ingénieur soit informé des méthodes scientifiques d'observation et de déduction du géologue parce que l'expertise géologique est " un type de recherche qui a ses règles particulières."

Una exposición del trabajo que la agrimensura geológica lleva consigo y algunos ejemplos en su aplicación en la investigación de proyectos de energía hidráulica. Todos los datos individuales, indica el autor, quien es un geólogo consultante, tienen que ser incorporados en las diversas interpretaciones del conjunto. Se crean y abandonan teorías a base de nueva evidencia hasta que a la terminación de su trabajo el geólogo está en condiciones de preparar un estudio acertado del terreno bajo examen. Los ingenieros deberían apreciar los métodos científicos de observación y de deducción del geólogo, debido a que una agrimensura geológica constituye " una actividad particularmente individualista."

GEOLOGICAL surveying is the art of observing and recording geological data and of drawing deductions therefrom. It is in part a factual matter, but differs from topographical surveying in that the mapper largely makes a choice of observations for record and is so much concerned with deductions. Various kinds of geological maps may be constructed as circumstances require. What may be called general purpose maps present all aspects of the geology, complete with geological signs and symbols, boundary lines, and different colours and ornaments for different rocks and rock-assemblages.

On the field map, from which the published map is compiled, the distribution of the solid rocks and overlying superficial deposits is shown, and topographic features are indicated wherever they serve a geological purpose. The map becomes a record of events which took place within the area, both events in the remote geological past and more recent occurrences such as the retreat of the great ice-sheets which covered Northern Europe and America in geologically modern times. The latter event has left its mark in unconsolidated sands, gravels and clays. The former can be read in the more ancient deposits now lithified to form sandstone, limestone, shales, and the many other types of solid rock.

The solid rocks are shown by dip arrows at selected exposures in the case of the stratified rocks, by rock-featuring ornaments or in other ways. Symbols, chiefly distinctive letters or abbreviations of terms, are added for indicating particular types of rock or rock-assemblages, as well as the geological age of the materials. Boundary lines are drawn between different geological subdivisions or rock-bodies, a solid line where the junction of the two rocks is observed or can be located within narrow limits; a broken line elsewhere, indicating uncertainty. Especially in the drawing of the broken line deduction takes the place of observation, and in the resulting picture much depends upon the judgment and insight of the mapper. The most likely place for the line to come is judged with reference to the topography as well as to other rock-exposures; the line is also an expression of the geological structure, which the geologist visualizes mentally.

A simple example is given in Fig. 1. Two exposures (A and B) of an identical limestone are situated a few hundred yards apart, with dip (inclination) of the bedding at each surface-outcrop directed towards the other. Each limestone is underlain by sandstone and overlain by shale. The picture formed in the geologist's mind is that the limestones will continue underground towards one another and will eventually unite. They are disposed in the form of a trough or syncline. The outcrops will also be connected at the surface around as it were the rim of the trough, below the covering of superficial deposits. One outcrop will therefore be extended by the mapper in both directions and be taken round in a curve to unite with the other outcrop. The lateral distance of the outcrop or, in other words, the length of the trough will depend upon whatever other evidence the mapper may collect in the neighbourhood. Perhaps this will consist of occasional exposures of the underlying sandstone and overlying shales, between which broken lines will be drawn to indicate the base and top of the limestone. If the direction of dip of the limestone at the two exposures is reversed, that is, if the beds are inclined away from one another, the structure will resemble a ridge, or what is termed an anticline (Fig. 1). Such ridges and troughs are not necessarily reflected in the surface contours of the land. Snowdon, for example, is structurally a syncline.

Another arrangement of strata (Fig. 2) shows two outcrops of an identical limestone dipping in the same direction and arranged *en echelon;* as in the previous case, they are underlain by sandstone and overlain by shales. Sandstone below the limestone farther to

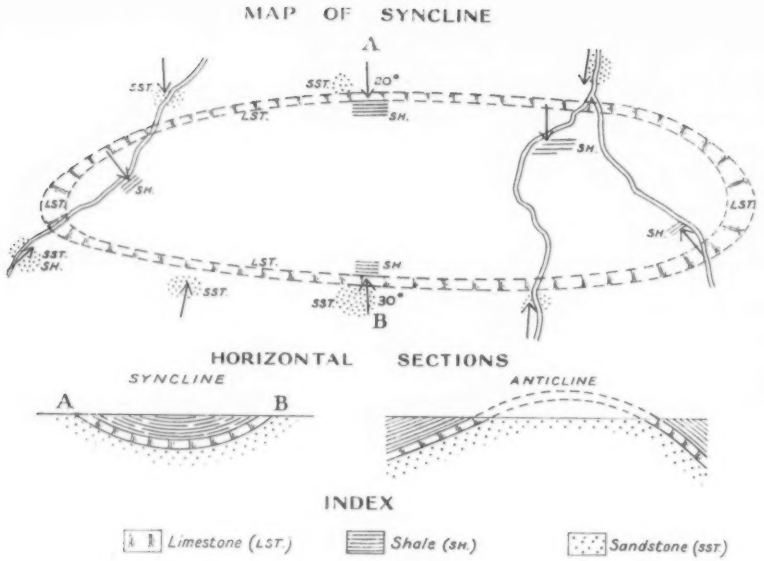


Fig. 1: A simple example, showing two exposures (A and B) of limestone

the dip is exposed at intervals back to the line of the other limestone-outcrop. In this case it is possible that one outcrop might make a sharp bend and so be joined up with the other—but, almost certainly, another explanation will be correct. The outcrops are more likely to have been shifted laterally by the movement along an intervening steeply inclined plane of fracture or fault, which extends between the outcrops in the direction of dip.

The mapping of superficial deposits—the so-called "drifts"—entails a different kind of technique (Fig. 3). For one thing the materials are well exposed or else can often be recognised from some characteristic of topography. Moraine deposited from glaciers occurs in hummocks with typical shapes. Boulder clay, the bottom moraine of ice-sheets, sometimes forms whale-back ridges (drumlins). Gravel deposited during melting of ice-sheets often occurs in smooth, rounded mounds. Alluvium bordering rivers or laid down in ice-dammed lakes makes level or slightly sloping terraces. The vegetation, too, may be a guide. For example, sand and gravel deposits may be distinguished from boulder clay in some places by means of a carpet of wild pansies on the former and a mat of rushes on the underlying clay. But the boundaries of the superficial deposits are in general uncertain, drawn according to experience coupled with a good deal of hypothesis, and they are indicated by a finely broken "peck" line.

Topography with its varied expressions is the geologist's constant conundrum. Every feature has a meaning, if only it can be understood. Yet in the reading of landscape, sometimes easy to decipher or else requiring knowledge of the recent or ancient turn of events in a particular locality, lies the greatest charm of field mapping.

The field geologist may find all his problems easy to solve but, again, many difficulties are often encountered. There is always much to learn in new country before understanding takes the place of uncertainty, while in well-known terrain progress may be rapid; but, however confident he may feel, the geologist must never slacken in the use he makes of his eyes. He has always to be on the look-out for the unexpected.

What, then, is the connection between this specialized technique and the assessment of water power schemes?

"*Elever un barrage c'est faire une expérience.*" Those concerned with water power will agree with this remark made by Professor Maurice Lugeon, the famous Swiss geologist—the building of a dam is in the nature of an experiment. It involves a risk, and this is closely bound up with geology, as events have shown. Failures during the present century have been mostly ascribed to defective foundations and leaky reservoirs. Many dams have given way along that vital rock-surface where the geologist's work ends and the engineer's begins. There are also examples of excellently constructed dams that have not retained a drop of water.

Every site and its environment have to be studied from the special point of view of the part they will have to play in the engineer's plans. No detail of evidence must be omitted from investigation. Even a minor geological circumstance may be of major importance for success or failure; or at least knowledge of it may save much unnecessary expense. An example will emphasize the need for specialized knowledge.

The Silent Valley dam near Belfast was placed on moraine overlying friable granite, and much difficulty was experienced in obtaining secure foundations. The significance of certain evidence available on the slope

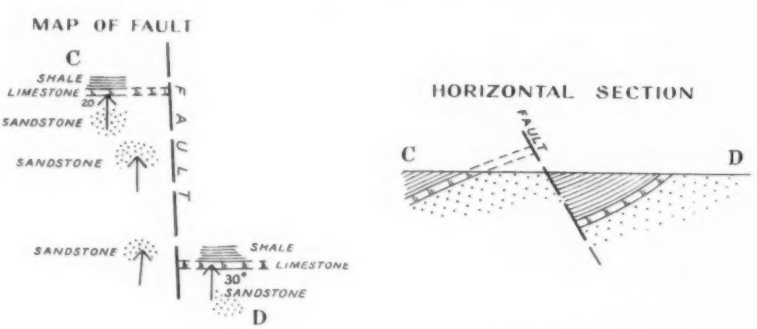


Fig. 2: Another arrangement of strata where limestone dips in one direction

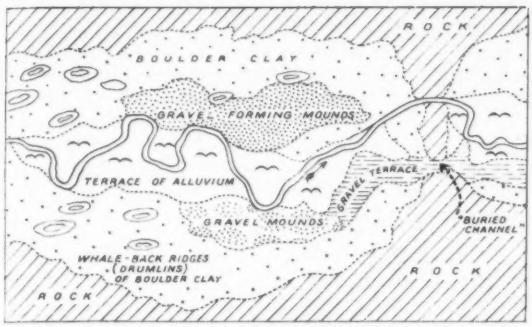


Fig. 3: The mapping of superficial deposits requires another technique

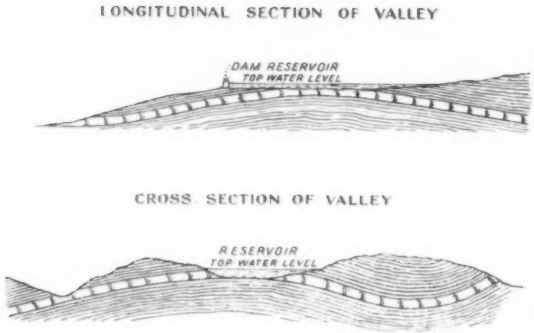
above the dam-site was not known at the time. This consisted of abundant thin veins of peculiar type which occurred elsewhere in the granite only in the vicinity of the "wall" of durable country rocks bounding the granite mass. The "wall" was therefore to be expected close to the site, and it is probable that water held up by it was responsible for the excessively deep weathering of the granite nearby.

Two types of valley will be considered, between which every kind of variation is possible. One type is essentially bounded by rock. The other is mostly covered along its floor and sides with superficial deposits. In the case of the rock-bounded valley, the nature of the rocks up to top-water level of the proposed reservoir is the geologist's first concern. Any permeable rock occurring below this level is a possible means of leakage. Limestone and open-textured sandstone are the most likely kinds to give trouble; and limestone, with its tendency to contain cavities by the enlargement of joints through solution, is the more dangerous of the two (Fig. 4). The rock, however, cannot be condemned out of hand, and many fine reservoirs in France and elsewhere are situated in limestone country.

The way in which a permeable belt of rock extends underground has also to be considered. In general, if such a belt forms part of a structural ridge or anticline, there is a possibility of leakage. If an anticline containing permeable strata crosses a valley, a permeable belt may be inclined down-valley and may extend below the dam (Fig. 5). Or, if the anticline runs along the valley, the belt will be inclined towards one or both sides of the valley, and may outcrop at a lower level in an adjoining valley (Fig. 6). In short, either a suitable rock or a suitable geological structure is required for ensuring water-tightness of a reservoir.

For the dam itself, the strength as well as the water-tightness of the rock is a matter of importance. In bedded rocks the relation between dip of strata and line of the dam has to be considered, up-valley dip being usually satisfactory. There may be local complications, such as those due to the effect of gravity upon a steep rock-face. For example, a rock-buttress projecting into the valley from one or both of its sides may appear an ideal dam-site (Fig. 7); owing, however, to the rock being traversed by land-slip or other less obvious fractures, the buttress may be unsound or require a prohibitive amount of strengthening. Another adverse condition is due to rock-creep. Highly inclined thinly bedded strata such as shales or slates with direction of strike ("level course") parallel to the valley sides are especially subject to this kind of gravity effect. The beds become bent over towards the river and so appear as if they were dipping away from the river. At the hidden bends the rocks are weakened by fractures, and the mass is in an unstable condition. This unenviable situation was encountered at a dam at Pinet (on the Tarn) in France, and great expense was incurred by special measures of excavation and construction and extensive grouting. It is another example of a relatively minor geological circumstance being of major im-

Fig. 4: Limestone and open-textured sandstone are possible sources of leakage. Here we show typical cavities in limestone; but the rock should not be condemned out of hand



Figs. 5 and 6: Two examples of an anticline containing permeable strata; there is a possibility of leakage

portance to the engineer and the success of his scheme.

In the case of a valley largely filled with superficial deposits not only the nature and disposition of the rocks but also the recent history of the valley are of interest. During his first reconnaissance the geologist is more especially concerned with two points, the likely shape of the original rock-bounded valley beneath the overburden of alluvial and perhaps older superficial deposits, and the relationship of the existing river-channel to the rock-valley. For example, if the river is out of the centre of the old valley at the dam-site it is possible that rock-head on one side of the site will slope away from the river; that is, towards the centre of the old valley (Fig. 8). Thus, a rock-abutment may be suitably situated on one side but on the other rock may not be encountered at the required height within a practicable distance. The unequal degree of suitability of the two sides of a dam is, for a variety of reasons, a recurring feature of sites.

If the region has been glaciated, as in most of Great Britain and the Alps, or in Norway, the more it becomes desirable to discover as much as possible about the shape of rock-head. The well-known case of the Vyrnwy Dam in North Wales where the engineers were aware that the valley had been glaciated and that the rock-floor was therefore likely to be uneven is an example of the value of argument based on hypothesis. A rock ridge was located by boring along the valley, and a vast amount of excavation was saved. To quote a case from the Scottish Highlands, a rock-ridge of this kind is exposed right across a valley; with a deep cut at only one place, where the present river is situated. More usually the rock bar has been breached by river channels of the glacial period, now filled with sand, gravel or moraine (see Fig. 3). Unless these "buried channels" are located and plugged, leakage through them may occur.

Filled-in rock-channels of glacial times may also run obliquely to the trend of a valley. They are cut by streams flowing around the snout of a retreating glacier, and are often filled in later. A dam-site extending up one of these hidden side-channels would be unfortunate indeed, and it is a possibility to be borne in mind. Lines of fault along which the rocks on either side have been broken and shattered are a source of danger and difficulty both at dam-sites and reservoirs. A fault zone, however, is very often narrow and filled with clay as well as broken rock, and so may not cause leakage.

In the case of tunnels a close study of the fault-system of the district is imperative. The alignment of a tunnel in relation to faults has to be considered. In mountainous country, where rock-featuring is well displayed, the position of a fault will usually be marked by a straight-running hollow on the surface (Fig. 9). The broken rock, however small in amount, is attacked and removed by denudation. A proposed line of tunnel set parallel or sub-parallel to such a hollow should avoid the vicinity of the latter.

Where rock is not well exposed there is no more difficult problem than the recognition and mapping of faults. The surrounding country as well as river and stream channels and hillsides in the vicinity of the tunnel have to be carefully searched. When the existence of a fault has been determined, the point at which it may be expected to cross the tunnel can usually be fixed only approximately, if indeed the fault reaches so far. Even with definite evidence that a fault will be encountered, it may not be possible to say whether the amount of shattered rock along it will be excessive or otherwise, or whether the breccia will carry a dangerous amount of water.

Undesirable directions of dip and strike of strata from the point of view of "overbreak" cannot often be avoided by re-siting a tunnel, since only a small amount of latitude in the siting is usually permissible; but the geologist may be able to suggest a site clear

Fig. 7: This rock-buttress suggests an ideal dam-site; but the valley must first be carefully surveyed for faults

of some especially difficult rock. For instance, very hard rocks (termed hornfels) often occur along the margins of granite masses. From knowledge of the shape of the granite-margin a line may be suggested which will run entirely in granite or at any rate largely evade the intractable hornfels.

One serious situation in regard to tunnels the geologist should be able to recognise, or at least to suspect. A wide drift-filled valley traversed by a river flowing in a rock-channel will illustrate this. Assume that it is proposed to divert the river by driving a tunnel from it to an adjacent valley where rock is again exposed on the valley side at the site of the outlet portal. Exposure of rock at each end of the stretch does not imply, however, that a tunnel will continue all the way in rock. For example, in the Scottish Highlands many years ago a tunnel was sited across a river valley of ancient, pre-glacial origin, partly filled in with glacial sands, gravel and moraine (see Fig. 7). The present river happened to be cutting into rock between the margin of the infilling and the original rock-side of the valley; but unfortunately it was the farther side from the outlet portal. Except for a short length of rock at either end, the tunnel had therefore to pass through the permeable materials infilling the old valley, and the tunnellers had to deal with several pockets of water-bearing sand.

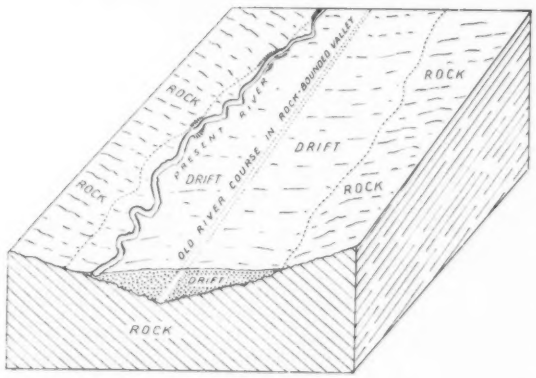


Fig. 8: Here the rock slopes away from the new river
Fig. 9 (below): An example of well-displayed rock-featuring

To conclude, geological surveying is a particularly individualistic activity, and the geologist works best alone. Each item of evidence collected has to be fitted in to his various interpretations of the scheme of things. Theories are made and discarded in the light of fresh evidence until, with the completion of the work, the geologist reaches final conclusions as to his assessment of the particular area he has examined. In the matter of engineering sites, geological investigations are required for estimating difficulties as well as for collecting facts. The engineer for his part has to appreciate the geologist's scientific methods of observation and deduction—he has also to weigh up a situation from all angles, being the final judge in his own case.

Some French Schemes

A PICTORIAL SURVEY

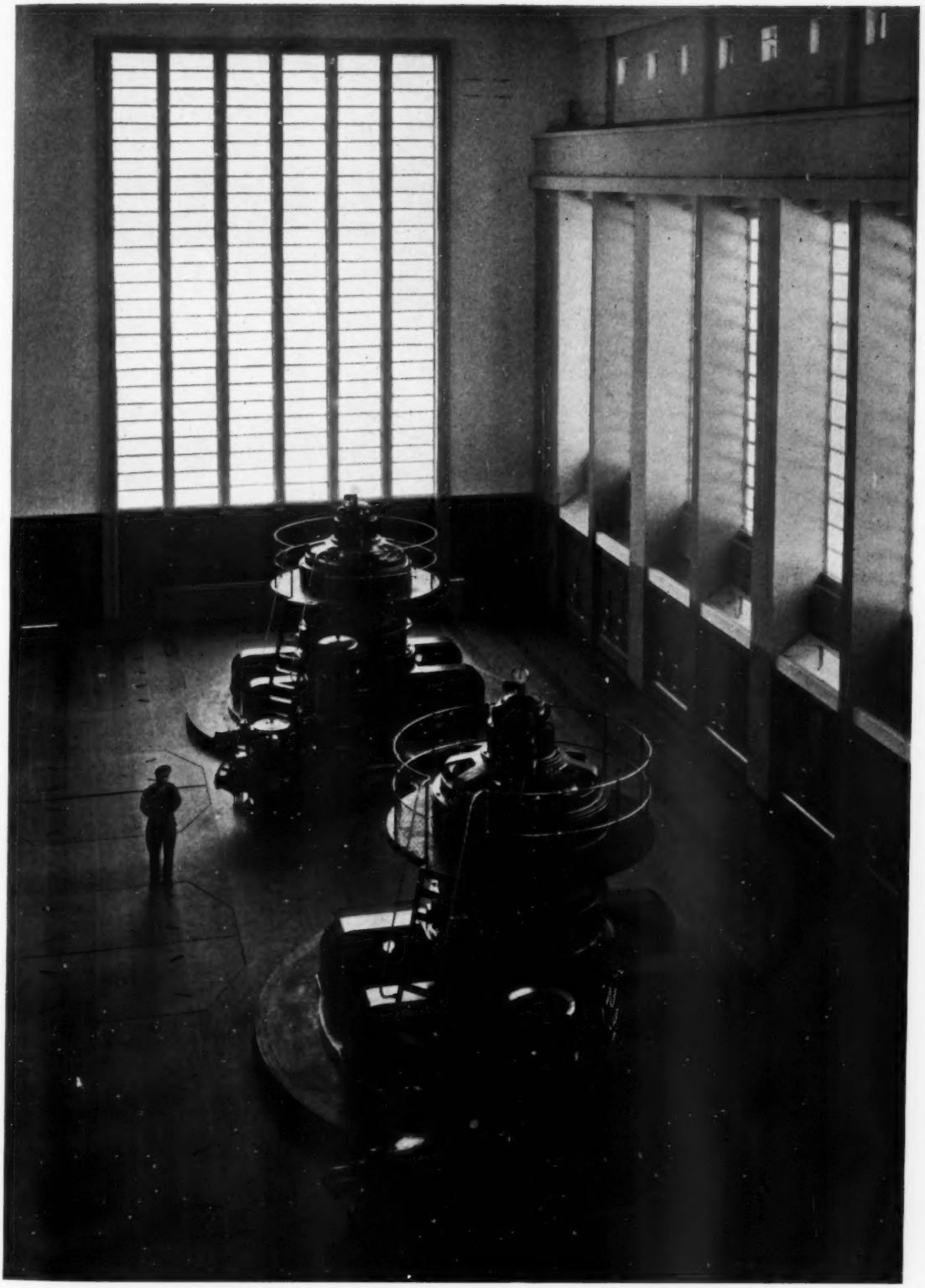
The following pages illustrate some examples of the hydro-electric plants administered by *Electricite de France*, which has a proud record for the development of the country's natural resources. These are divided into nine areas, three in the Alps, two in the Pyrennean region and three in the *Massif Centrale*, with a remaining region for other isolated developments in France.

AMONG the stations in the *Massif Centrale* are those on the River Maronne, where three hydro-electric developments have taken place. They comprise the reservoir barrage of Enchanet, which provides a reserve of 73 million cubic metres (at the highest point); lower down the river the barrage of Gour Noir, feeding the station at St. Geniez-ô-Merle; while at the lowest point is the barrage de la Broquerie. The three stations have an installed capacity of—Enchanet 28 megawatts; St. Geniez 34 megawatts; and la Broquerie 22 megawatts, making 84 megawatts in all and an annual output of 280 MWh.

Construction work on the Saint Geniez station (Figs. 1 and 2) was started in 1940, but because of war-time difficulties it was not put in service until 1946. The net head is 115 metres and the power house contains two sets, each fed by a separate pipeline and comprising Francis type water turbines arranged vertically, developing 23,700 h.p. at 375 r.p.m. while using 17.5 cubic metres of water a second. The alternators generate at 12 kV.

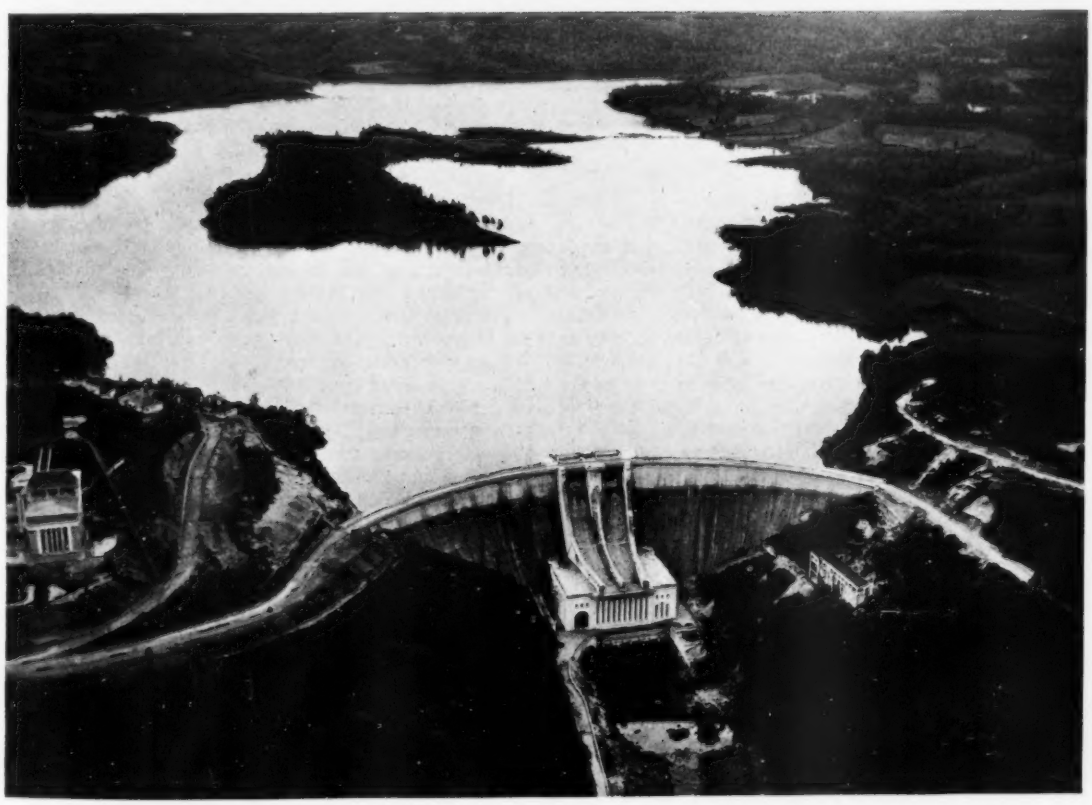
The station is constructed on what has come to be regarded as classic lines; that is to say the alternators are supported by beams of reinforced concrete, which in turn are supported on concrete pillars disposed between the sets and carrying the walls of a turbine room of sufficient height to provide for the main-

One of the hydro-electric stations on the River Maronne: Saint Geniez-ô-Merle



Part of the machine room at the 34 megawatt station at Saint Geniez-ô-Merle

Above: Work in progress on the raising of the dam at Lac de la Girotte, in Haute Savoie
Below: A detailed view of the work in progress at the above site: in the background, Mont Blanc



Above: St. Etienne-Cantales: general view showing dam, housing arrangement for staff, and substation
Below: A closer view of the dam at St. Etienne-Cantales, showing the "ski-jump" spillway

Construction work on the 255 MVA station at Chastang, on the Dordogne

tenance and inspection of the turbines.

Much of the power feeding northwards to Paris is derived from the *Haute-Savoie* region in the Alps, and among the projects in that area is the Girotte barrage (Figs. 3 and 4). The Girotte lake situated at the foot of the Dounet Valley is used as a seasonal regulation reservoir for the plants at Belleville, Hauteluce, Beaufort, Queige, Roengers, and Venthon, which are situated along the Doron de Beaufort river as far as its confluence with the Arly. To control the flow from the lake a barrage having a useful height of 30 metres and a length of 500 metres was commenced in 1942; a super elevation, giving an increase of 60 million cubic metres in the volume of stored water, was completed in 1948. It is of the cylindrical arch type, with the cylinders anchored to the rock by means of spherical portions at the base.

Another station in the *Massif Centrale* is that on the Cère river. The Saint Étienne-Cantalès station (Figs. 5 and 6) forms part of the programme of re-equipment which was put forward in 1938. The station comprises a dam of 70 metres in height; at its base is the power house, which is provided with two 30,000 kVA alternators. A third set is envisaged, generating at 12 kV and constructed by *La Société Générale de Constructions électriques et mécaniques (Als-Thorn) et la Société anonyme des Aletiers des Charmilles.*

They are all designed to function with heads varying between 62 and 35 metres. An interesting point in the station design is the spillway arrangements, whereby surplus water is discharged by a concrete spillway over the station buildings and out in a spectacular cascade to the tailrace. This feature is clearly seen in the photograph (Fig. 5).

An important station which can be classed amongst the largest and most impressive hydro-electric installations in France, the barrage at St. Etienne-Cantales forms a notable conclusion to the utilisation of one of the most beautiful rivers of the *Massif Centrale*. It was constructed under enormous difficulty due to the war period, since communications between what was for a considerable period the Occupied Zone and the Southern Zone, were extremely difficult and rendered progress almost impossible. From 1939-1942, in spite of every war hardship, construction proceeded. In the latter year, the lack of cement was particularly felt, and it was not until 1944 that work was resumed at full pressure. Certain materials were impossible to obtain, and various substitutes had to be used. Copper, bronze, stainless steel, and paints were especially difficult and many ingenious substitutes were found.

The Chastang station (Fig. 7) is on the Dordogne river, also in the *Massif Centrale*, and comprises an installed capacity of 255,000 kVA under a gross head of 72 metres. This is one of the most recent stations in the programme of *Electricite de France*, to whom we are grateful for the use of these photographs.

Hydro-Electric Production in France

Report by M. FERRY, of the Direction de L' Exploitation Electricite de France

THE hydrological year from October 1, 1948, to October 1, 1949, has been characterised in France by insufficient precipitation which has been quite exceptional, its duration lasting not only through the spring and summer but also during the autumn and winter. It has resulted in hydro-electric production of an extraordinarily low figure for all the water power areas except the glacial terrain, where there has been a normal flow during the summer.

The following table, referring to the two periods October to March and April to September and the twelve months October, 1948, to September, 1949, shows:—

1. The effective hydro-electric production of each of the three major regions of France, and of the total production.
2. The theoretical production corresponding to the water flow after corrections for seasonal movements in reservoirs and water losses of various kinds.
3. The mean production calculated from the period of October, 1921, to September, 1948.
4. The coefficient of productibility of 1948/49 in relation to proceding mean levels.

The curves show the coefficient of production of each of the main regions (and their total production) is shown from 1922 to 1949 for the first period — from October 1 to March 31; another curve gives similar information for the same years, but for the April to November season.

These curves show clearly that 1948/49 was the worst for 28 years. The deficit in hydro-electric production in the region of the *Massif Central* has been particularly catastrophic, as it has fallen to 24 per cent. of the mean figure; previously production has never been less than 60 per cent. of the mean. This has brought about a lowering of the seasonal reservoirs, which is quite abnormal at the end of the summer season.

At the end of September the reservoirs in the Alps were filled only to 54 per cent. of their capacity in terms of energy, and those of the Pyrenees to 40 per cent. In the *Massif Central* the mean content for all the reservoirs was 33 per cent. At the start of November, 1949, they had reached a minimum of 27 per cent.; but fortunately heavy rainfall and the restrictions in force enabled the reservoirs to be filled to 47 per cent. of their capacity by the end of November.

ENERGY PRODUCED BY FRENCH HYDRO-ELECTRIC STATIONS DURING YEAR OCTOBER 1, 1948, TO SEPTEMBER 30, 1949

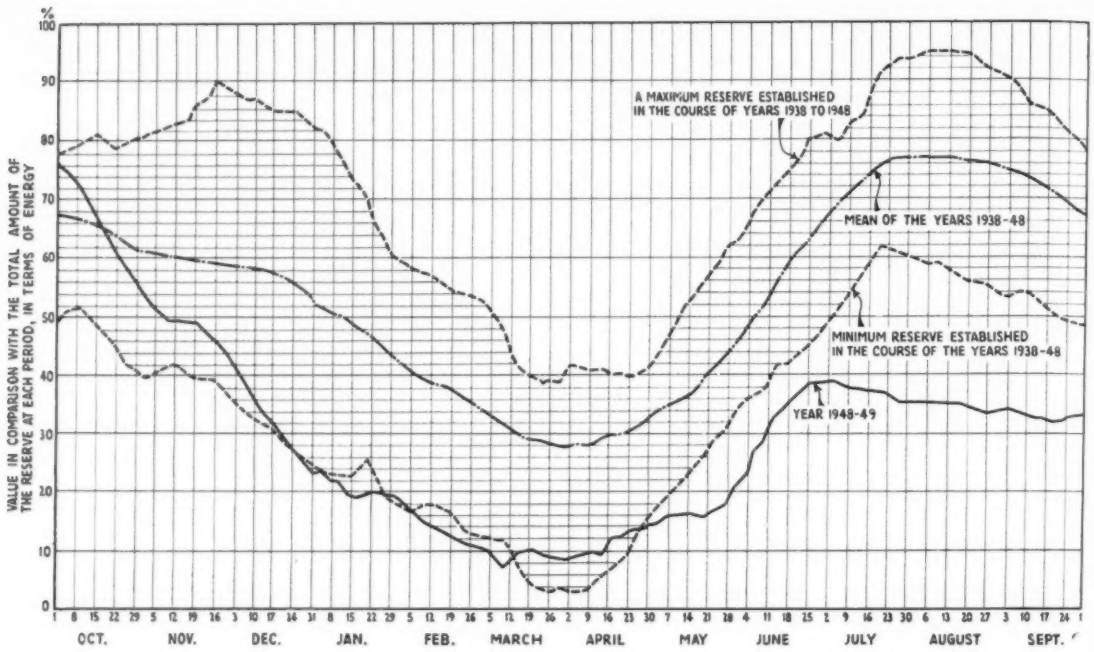
(In millions of kWh; on the basis of the equipment existing at the 1st January, 1949).

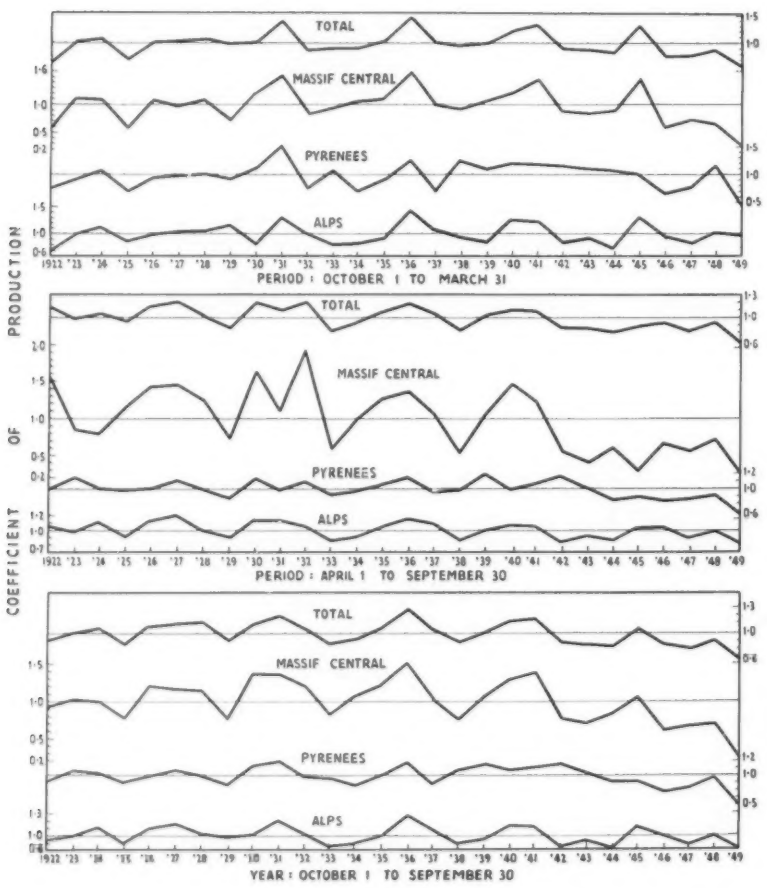
REGIONS	Effective Production	Theoretical Production in Relation to Available Water	Mean Production	Coefficient of Production
	[Period: October to March]			
ALPS - -	3.065	2.783	3.310	0.84
PYRENEES -	0.750	0.518	1.130	0.46
MASSIF CENTRAL -	0.967	0.737	2.810	0.26
TOTAL - -	4.782	4.038	7.250	0.56
	[Period: April to September]			
ALPS - -	4.297	4.708	6.020	0.78
PYRENEES -	1.214	1.384	2.180	0.63
MASSIF CENTRAL -	0.365	0.317	1.550	0.20
TOTAL - -	5.876	6.409	9.750	0.66

ANNUAL PRODUCTION

[Period: October 1 to September 30]

REGIONS	Effective Production during year 1948/49	Theoretical Production in Relation to Available Water	Mean Annual Production	Coefficient of Production
ALPS - -	7.362	7.491	9.330	0.80
PYRENEES -	1.964	1.902	3.310	0.57
MASSIF CENTRAL -	1.332	1.054	4.360	0.24
TOTAL - -	10.658	10.447	17.000	0.61





The curves above show the levels of the seasonal reservoirs of the French hydro-electric system; the three curves on the left showing the coefficient of production of each of the main regions (top, October to March; centre, April to September; bottom, over yearly periods).

The effect on the industrial life of France of these unprecedented periods of drought has been, to some extent, mitigated by the ability of the thermal stations to produce a greater output than had been considered possible in view of the age of some of the installations and of fuel difficulties. Nevertheless, severe restrictions had to be imposed in many regions including the Parisian area, in the late autumn.

Since the figures given in the table were compiled, rainfall statistics have been much more satisfactory and nearer normal.

Concrete for Dams

A review of present day practice, by M. J. Tomlinson, A.M.I.CE., A.M.I.Struct.E., and A. A. Trower. Consideration is given to the types of cement and aggregates used in different parts of the world; and the compounds that are added to increase workability, reduce heat generation and prevent chemical reaction in concrete. Other aspects including the mixing, transport and placing of concrete ; and its surface finishing and curing are briefly discussed

SINCE the beginning of this century concrete has been used to an increasing extent in the construction of large dams for hydro-electric or water supply purposes, and today it has almost completely replaced stone masonry, although large earth-fill dams are still widely used where site conditions and local materials favour this type of construction.

The largest concrete dams in the world are, as might be supposed, in the United States. These include Hoover Dam (formerly called the Boulder Dam[1]), 726 feet high and containing 3,250,000 cu. yds. of concrete, and Grand Coulee, 550 ft. high and containing 10,500,000 cu. yds. of concrete.

Among notable concrete dams in Europe are Chambon, Genissiat[2], and Castillon, in France, which are 450, 345 and 327 ft. high respectively; and Grimsel (377 ft.) and Rossens Dam[3] (272 ft.) in Switzerland. In Great Britain there are no concrete dams approaching the foregoing in magnitude. The largest at Claerwen[4] in central Wales is still under construction and will be 184 feet high, containing 361,000 cu. yds. of concrete. There are also a large number of concrete dams in Scotland which have been completed or are under construction for the North of Scotland Hydro-Electric Board and other authorities. Among these, Laggan Dam[5] for the Lochaber Water Power Scheme is 177 feet high and was completed in 1934.

Although a number of instances of failure of concrete dams are recorded in engineering literature, these have been almost entirely due to foundation weakness; structural failure of the water retaining material is virtually unknown. Nevertheless there have been many instances of deterioration of concrete in dam structures due to weathering under extremes of climate, or erosion from flowing water. These cases serve to emphasize the need for the highest possible standards of quality in the materials and workmanship for the concrete forming the dam and its ancillary structures. The quality of concrete required and the factors influencing the strength and proportioning of concrete mixes are discussed in this review.

General Considerations

The main requirements of concrete for dams are—(a) high strength to resist the designed stresses, (b) watertightness against percolation through the upstream face, (c) durability to withstand erosion and extremes of climatic conditions, (d) low heat of hydration in the interior of large masses of setting concrete, and (e) workability sufficient to enable the concrete to be placed without segregation or honeycombing using normal construction procedure.

STRENGTH (a).—In most water retaining structures a high compressive strength is required to withstand the stresses set up from the pressure of the impounded water and from shrinkage and temperature movements. Compressive stresses of about 2,000—3,000 lb./sq. in. are usual, but stresses up to 5,900 lb./sq. in. have been accepted in the design of some structures[6].

The strength of a dense, well-compacted concrete depends solely on the water-cement ratio: by using a low water-cement ratio high strengths may be obtained, but only by sacrificing the workability which the mixing water gives to the concrete. The required workability can be achieved either by adding more water (with consequent loss of strength and increase of shrinkage), or by increasing the cement content, which will again increase shrinkage and also increase the temperature rise in the hardening concrete from the heat of hydration of the cement.

In massive dam structures it is essential to keep shrinkage and temperature rise down to the absolute minimum. This usually means the employment of two or more qualities of concrete in an endeavour to meet the various conflicting requirements.

The hearting or mass of concrete in the interior is designed with the main object of keeping shrinkage and heat of hydration low. To this end a large sized aggregate is used with a low cement content. Workability is achieved by increasing the water-cement ratio, which generally ranges from 0.60 to 0.75 with strengths from 4,000 to 3,000 lb./sq. in. at 28 days.

On the exterior faces of the dam, and particularly on the spillway section, a dense concrete is essential, combined with a sufficient workability to enable the concrete to be worked around reinforcement and expansion joints, and to give a smooth close-knit surface when the forms are removed. Hence a fairly rich concrete must be provided. The higher cement content allows lower water-cement ratios, usually varying from 0.45 to 0.60, with 28-day crushing strengths ranging from 5,500 to 4,000 lb./sq. in.

Since concrete of this quality is liable to greater shrinkage and temperature rise than the hearting concrete, the thickness of the face layer should not be more than 5 feet. Some random figures for water-cement ratio and compressive strengths of dam concrete are shown in Table I.

Fig. 1: Bitumastic Paint applied to the surface of Clunie Dam as a protection against the effect of water containing organic matter

TABLE I.

Dam	Location	Exterior Concrete		Interior Concrete	
		Water-Cement Ratio	Crushing Strength at 28 days (lb./sq. in	Water-Cement Ratio	Crushing Strength at 28 days (lb./sq. in.)
Laggan (5)	Scotland	0.40	4700	0.55	2700
Galloway (7)	,,	0.53§	5500§	0.73§	2940§
Pitlochry	,,	0.55	4800	0.68	3300
Rossens (3)	Switzerland	0.64	5690-7112*	0.64	5690-7112*
Bluestone (8)	Virginia, U.S.A.	0.49	5480†	0.62	4270†
Norfolk (9)	N. Arkansas, U.S.A.	0.54	4797†	0.69	3043†
Douglas (10)	Tennessee ,,	0.55	5500‡	0.75	3000‡
Claytor (11)	Virginia ,,	0.57	4800†	0.75	3200†

§ Estimated from published figures for 7 day crushing strength.
* 25 c.m. cubes.
† 12 in. x 6 in. diam. cylinders.
‡ Estimated from water-cement ratio.

WATER-TIGHTNESS (b).—It is, of course, essential for the dam to be completely water-tight. Leakage is liable to occur through shrinkage cracks and horizontal construction joints. Leakage through shrinkage cracks can be avoided, or greatly minimized by a low water-cement ratio, a large maximum-sized aggregate to reduce the amount of fines in the mix, the use of a rich concrete only in the surface layer, careful attention to detail in the laycut and design of expansion and contraction joints, and by the construction procedure.

Precautions to be taken in avoiding leakage through construction joints will be discussed later in the article.

DURABILITY (c).—Dams are frequently sited in mountainous terrain exposed to extremes of hot and cold climates. These alternating cycles of high and low temperature, together with the effects of ice forming at the water-line and spillways, are the most frequent causes of deterioration of dam concrete.

In addition to weathering, the spillways and outlet tunnels are liable to severe erosion by water flowing at high velocities. At Hoover Dam after only four months of operation the Arizona spillway tunnel was eroded to a depth of 36 feet by water flowing down the tunnel inclined at 50° to the horizontal[12]. At Grand Coulee Dam severe erosion was observed in the spillway bucket after five years of operation[13].

Small irregularities in the surface finish of the concrete caused by honeycombing or defects in the formwork can set up cavitation in water flowing at a high velocity, with consequent erosion occurring at a progressively increasing rate.

Durability of the exposed surfaces can be ensured

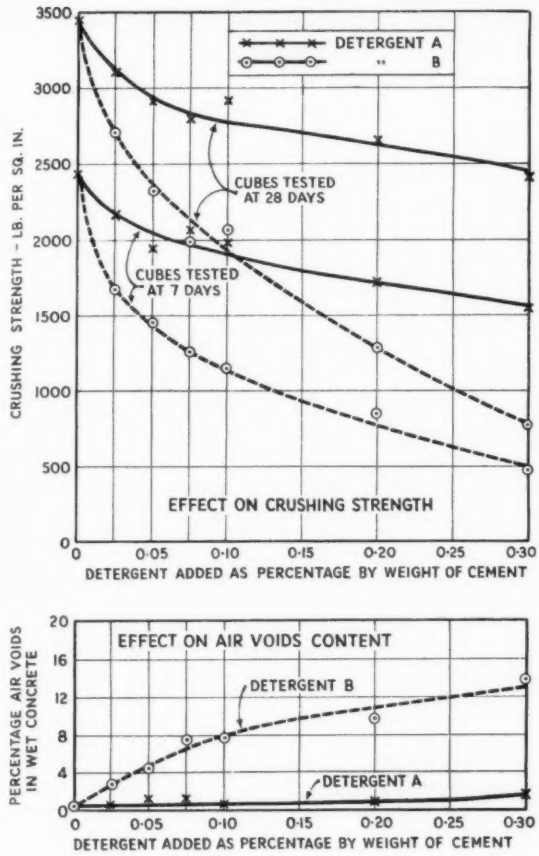

DETERGENT A
" B
CUBES TESTED AT 28 DAYS
CUBES TESTED AT 7 DAYS
EFFECT ON CRUSHING STRENGTH
CRUSHING STRENGTH - LB. PER SQ. IN.
DETERGENT ADDED AS PERCENTAGE BY WEIGHT OF CEMENT
EFFECT ON AIR VOIDS CONTENT
DETERGENT B
DETERGENT A
PERCENTAGE AIR VOIDS IN WET CONCRETE
DETERGENT ADDED AS PERCENTAGE BY WEIGHT OF CEMENT

Fig. 2: Graphs showing the effect of detergents on the crushing strength and air voids content of concrete (1 : 6 mix, normal Portland cement, London River Gravel, $\frac{3}{4}$ in. max. size, and sand; water-cement ratio: 0.50)

by providing a surface layer, usually five feet thick, of a fairly rich high quality concrete, and having a higher cement content and lower water-cement ratio than the interior concrete. Typical figures for water-cement ratio and crushing strengths of the face concrete are shown in Table I.

In U.S.A., where climatic conditions are more severe than in this country, it is becoming common practice to use an air-entraining agent to increase the frost resistance of the concrete. Admixtures of this type serve the purpose of increasing the workability of the concrete, thus permitting a lower water-cement ratio, without the need for more cement (if a lowering of strength is admissible). By this means the quality, and hence the frost resistance, of the concrete is improved. However, the use of air-entraining or wetting agents involve a reduction in density and loss of strength (up to 20 per cent. for normal additions of wetting agent); therefore unless the lower strength of the face concrete can be accepted more cement or less water will have to be added, and no advantage will have been gained by using the agent. This subject will be discussed further under "Admixtures."

In Great Britain dams are frequently sited to impound moorland water which may have a high organic content, causing some deterioration in concrete. Fig. 1 shows a bituminous compound being applied to the face of Clunie Dam in Scotland to give protection against organic attack.

LOW HEAT OF HYDRATION (d).—The rise in temperature which always accompanies the setting of concrete is a serious problem in the construction of large concrete dams, since the subsequent cooling of large masses of concrete can cause severe strains if the interior of the concrete is at a substantially higher temperature than the surface[14].

Among other things the amount of heat evolved in setting concrete depends upon:—

(i) Type and quality of cement.
(ii) Size and shape of the mass.
(iii) Nature of the radiating surface of the mass.
(iv) Water-cement ratio.
(v) Degree of aeration of the cement.

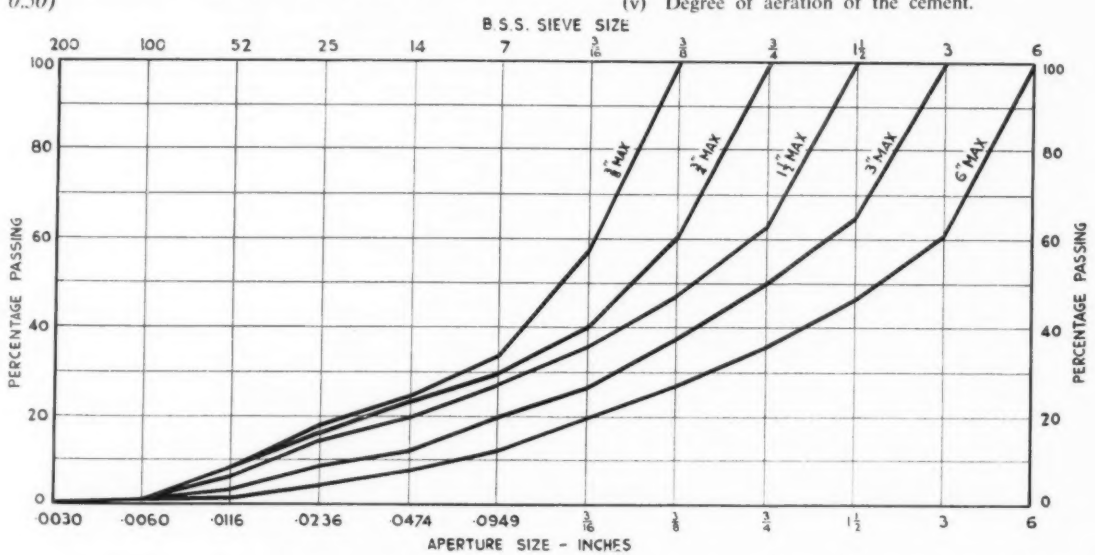


Fig. 3: General form of grading curves for aggregate having maximum sizes of 6 in., 3 in., 1½ in., ¾ in. and ⅜ in.

Woods, Steinour and Starke[15] have shown that the proportion of tricalcium aluminate in the cement has a marked effect on the heat of hydration as is shown by the considerable rise in temperature of high alumina cement. A low heat Portland cement having a low tricalcium aluminate content is widely used in U.S.A., and its use is being extended to dams in Great Britain[1]. The special properties of this cement will be discussed later.

Data collected by the Building Research Station[14] has shown that the temperature rise in a number of structures varies from 0.05° to 0.15°F. per lb. of cement per cubic yard of concrete, which emphasises the desirability of keeping the cement content as low as possible.

TABLE II.

Dam	Location	Admixture	Percent. by weight of cement	Purpose
Genissiat (2)	France	Slaked Lime*	18	To increase workability.
Altus	U.S.A.	Pumicite	35	To counteract alkali-aggregate reactivity and lower heat of hydration.
Davis	U.S.A.	Calcined Shale	20	Do.
Friant	U.S.A.	Pumicite	20	Do.
Bull-Shoals	U.S.A.	Natural cement	25†	To give improved workability and lower heat of hydration.
Bluestone (8)	U.S.A.	Air-entraining agent	0.6-0.8	To give improved workability and frost resistance.

* Added to slag cement.
† Containing air-entraining agent to give 6% entrained air.

It is customary to divide a dam structure into separate monoliths by means of permanent expansion and temporary construction joints. The size and shape of the monoliths have an important effect on the rate of dissipation of heat, and put practical limits on the size of the concrete pours and the time interval between successive pours in the same monolith.

The monoliths at Hoover Dam were 30 feet wide, separated by 2 feet wide spaces filled in six months later[1]. Similarly at Rossens Dam[3], the 44 feet wide monoliths were separated by 5 feet wide spaces, and dissipation of heat was assisted by forming 5 feet diameter ventilation chimneys in the centre of each monolith, connected by an elliptical tunnel at their base.

In moderate-sized dams elaborate cooling methods are not necessary; but it is usual to limit the size of monoliths to 50 feet × 50 feet × 5 feet high, with a minimum period of four days between the pouring of successive lifts in the same monolith. Of the other factors, the nature of the radiating surface, and degree of aeration of the cement, do not greatly affect the basic design of dam structures, and a low water-cement ratio is essential both to lowering the heat rise and minimizing shrinkage cracking.

WORKABILITY (e).—The use of modern concrete mixing and placing equipment, including vibration, enables concretes of fairly low workability to be used. In the interior of the dam low to medium workability is needed, with a compacting factor[16] of 0.85 to 0.92 (corresponding to 1 in. to 2½ in. slump). On the face, it is often necessary to work the concrete around reinforcing steel, expansion joints, and holding down bolts, requiring a medium workability with a compacting factor of 0.92 to 0.95 (2 in.—4 in. slump).

Constructional Materials

CEMENT.—Normal Portland cement is used for dam construction in Great Britain and the Continent, but in U.S.A. it is now common practice to use low-heat cement on large dams. It is not permissible to use high alumina cement in view of the high temperature rise during hydration. Rapid hardening Portland cement is open to the same objection.

Low heat cement is specially manufactured for concrete which is placed in large masses. In Great Britain it is covered by B.S.S. No. 1370, 1949, and is being used on the construction of Claerwen Dam[4]. The low heat rise is obtained by a reduction in the content of tricalcium aluminate, with a coarse grinding which gives a slow generation of heat. This type of cement is slow setting, the initial setting time is specified as one hour, compared with 30 mins. for normal Portland cement. Special requirements in B.S.S. 1370 are a specific surface of not less than 3,200 sq. cm. per gram, and the heat of hydration should not be greater than 65 calories per gram at seven days, or 75 calories per gram at 28 days.

Natural cements and pozzolanic cements show a low heat rise, and slag cement was used in the construction of Genissiat Dam in France for the same reason[2].

USE OF ADMIXTURES.—Various compounds have been mixed with the cement in dam construction, the main purposes being to increase workability, lower the heat of hydration, or as a precaution against chemical reaction between the cement and certain types of aggregates.

To increase workability, air-entraining agents, wetting agents, or plasticisers have been used. These are usually industrial detergents obtained as a by-product of petroleum distillation, or powdered resins. Their effect is to lubricate the mix by the formation of minute air bubbles, and their use is necessarily accompanied by a loss in density and strength.

The effect of varying quantities of wetting agents on the density and strength of concrete has been the subject of a laboratory investigation by the authors' firm[17] and some of the results obtained are shown in the graphs in Fig. 2.

The advantages gained by using air-entraining agents are doubtful where well graded aggregates are used, when increased workability is given by only small increases in water content. However, there may be cases where ideal grading cannot be economically obtained, and the addition of an air-entraining compound may give sufficient workability without increasing the cement and/or water content, to values where heat rise and shrinkage would be detrimental. Addition of such materials as calcined shale or pozzalana slow the rate of hardening and reduce the heat rise.

Alkali-aggregate reactivity is not a problem in Great Britian as it is in many parts of U.S.A., where serious deterioration was caused in the concrete of Parker Dam less than two years after its completion. Admixtures such as trass, pozzalana or calcined shale are used as a precaution against disintegration of the concrete from this cause.

Admixtures used in various concrete dams are shown in Table II.

TABLE III.

Weights of Constituent Materials of 1 cu. yd. of Concrete for various Dams

Dam	Location	Type of Concrete	Admixture	Cement lb.	Other Material lb.	Water lb.	Coarse Aggregate				Sand		Average Crushing Strength at 28 days lb./sq. in.
							6"–3"	3"–1½"	1½"–¾"	¾"–3/16"	Natural	Artificial	
Bluestone[8]	U.S.A.	Interior	—	329		204	791	689	587	485	871	300	4270
			0.6—0.8% Air Entraining Agent	282		171	881	722	588	481	251	779	3030
		Face	—	423		206	773	674	573	474	851	294	5480
			0.6—0.8% Air Entraining Agent	423		189	769	670	571	471	257	798	4565
Davis	U.S.A.	Interior	20% Calcined Shale	309	62	215	703a	739a	844a	352a	879a	—	—
Norfolk[9]	U.S.A.	Interior	—	282		194	698b	682b	693b	354b	1130f	80g	3043h 3790i
		Face	—	376		202	720b	640b	584b	527b	1055f	—	4797h 6015i
Pitlochry	Scotland	Face	—	560		308	—	—	895k	1117k	1000l	—	4800

a—Bin sizes were: 6"-2½", 2½"-1½", 1½"-¾", and ¾"-No. 4, gravel and sand. b—Mixture of limestone and crushed gravel. f—River Sand. g—Limestone Dust. h—Low heat cement. i—Moderate heat cement. k—Crushed granite. l—River sand.

AGGREGATES.—It is the normal practice for the engineer to devote exhaustive study to the siting of a dam in relation to economics, rainfall and run-off, geology, and foundation conditions. The same careful study should be given to the selection of constructional materials; and in particular, to concrete aggregates. The whole region should be explored with a view to obtaining the best materials which will combine with the cement to give the densest and most workable concrete, meeting the designer's requirements for quality, strength and durability.

Suitable combined grading curves for coarse and fine aggregates are shown in Fig. 3 for 6 in., 3 in., 1½ in., ¾ in., and ⅜ in. maximum sizes. They emphasize the appreciable reduction in the proportion of fine aggregate given by an increase in the maximum size. For a 6 in. maximum-sized aggregate, only 20 per cent. of fine aggregate is required compared with 36 per cent. for 1½ in. stone. Therefore, by using the largest sized aggregates, the proportion of fines, and hence the cement and/or water content required to give workability, is correspondingly reduced. This has an important bearing on the potential shrinkage and temperature rise.

Some years ago, "plums" were embedded in the concrete to give, in effect, a reduction in cement content of the whole mass, but this procedure is uneconomic in manpower, and has been discarded in favour of using the largest possible size of aggregate. The maximum practical size is generally accepted to be 6 in. Larger stone does not suit crushing and screening plants, although 9 in. stone was used in the Hoover Dam. In Great Britain the maximum specified size is generally 3 in. This size has been exceeded only in the Claerwen Dam[1] where 6 in. stone is being used at the present time.

If natural sand is not available for fine aggregate, recourse must be made to producing artificial sand by the crushing of stone. The fine aggregate produced is not altogether satisfactory, since the particles are generally angular and dusty, thus requiring a higher water content. Natural sand should be used, if at all possible, if only as an admixture to the artificial sand.

The quality of the aggregates must, of course, be beyond question. Micaceous, shaley, or laminated stone should not be used; and the sand should be free from silt, clay, or organic impurities.

If two or more types of stone are available, detailed laboratory tests should be made to determine the best type to give the required strength and workability, with the smallest water content. Proportions of the various constituent materials to give one cubic yard of concrete are shown for selected dams in Table III.

The reduction in cement and water content, and the decrease in compressive strength, brought about by the use of air-entraining agents will be noted.

Concrete Mixing and Placing

MIXING.—The speed of pouring concrete in a large dam is governed, not by the available mixing plant but by the limits specified in the rate of concreting, to enable the heat to be dissipated before placing successive lifts.

On large jobs it is often the practice to instal a battery of mixers, rather than to provide one or two large units. This gives greater flexibility to deal with varying rates of placing, and allows different classes of concrete to be mixed and placed simultaneously. Thus on Genissiat Dam[2], a battery of six 2 cu. yd. mixers were installed. On the Hoover Dam[1], 4 cu. yd. mixers were provided with a total output of nearly 15,000 cubic yards in 24 hours.

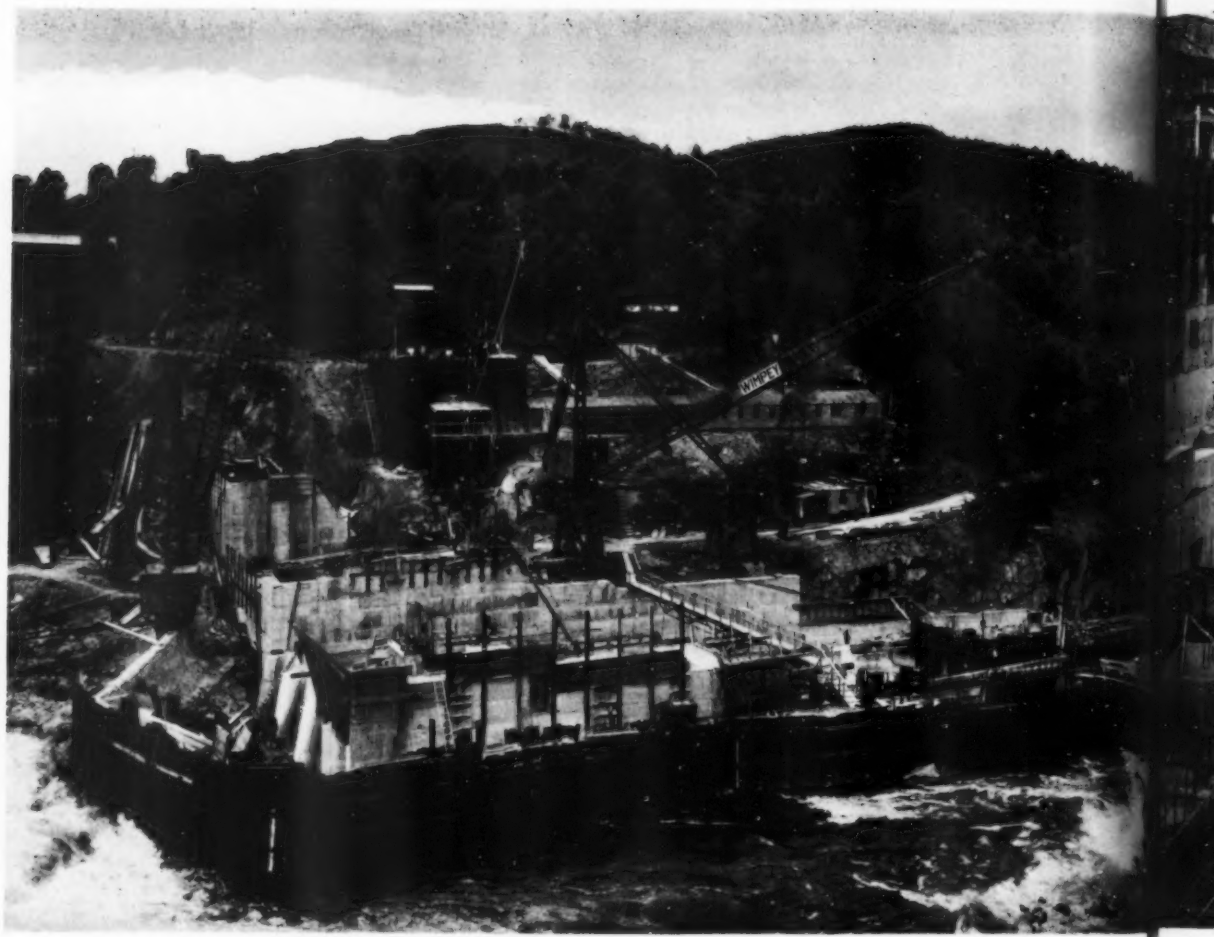


Fig. 4: General view of concrete work at Clunie Dam showing batching plant

Weigh-batching of aggregates, cement, and water is essential on large jobs to ensure uniformity in the concrete and economical control of production. Volume-batching of aggregates is still used to a large extent on smaller jobs.

Separate bins are required for the storage of various sizes of aggregate, to give uniformity in grading. The usual sizes are 6 in.—3 in., 3 in.—1½ in., 1½ in.—¾ in., ¾ in.—⅜ in., ⅜ in.—$\frac{3}{16}$ in., and sand. Volume measuring hoppers should be deep, with a small plan area, to minimize errors in gauging. Frequent checks of the water-content of fine aggregates are, of course, necessary with volume batching, since the bulking of sand at varying water content can cause serious errors in volume measurements.

On large mixing plants the cement is usually stored in bulk, in silos above the mixer; but batching in units of a bag is more common on smaller plants.

In hot climates it is necessary to erect some form of shade for aggregate stock-piles and bins, and to cool the mixing water to 35°F. to ensure that the concrete is placed at a temperature between 50 and 70°F.; thus keeping the temperature rise down to a safe value. Chipped ice has been mixed with the aggregate for this purpose on some jobs. On the other hand, in cold weather, it is necessary to take precautions by covering or heating the aggregates and mixing water, to ensure that the temperature of the fresh concrete does not fall below 40°F.

The batching plant used at Clunie Dam is shown in Fig. 4. The storage bins were five in number and contained 3 in.—1½ in., 1½ in.—¾ in., ¾ in.—⅜ in., ⅜ in.—$\frac{3}{16}$ in. stone and sand. They were fed by lorries from a high level roadway. The bins discharged into volume measuring hoppers below each bin, and the batched materials discharged by gravity to the 1 cu. yd. mixer. The cement was handled in bags from the storage shed to the mixer hopper.

TRANSPORTING CONCRETE.—With the concrete used in present day dam construction it is no longer possible to use chutes or belt conveyors for transporting the concrete from the mixer to the forms because of the risk of segregation. Bottom dumping skips are now almost universally employed; being handled by cableway, derrick-crane, or rail wagons; or a combination of these methods. The size of skip depends on the size of mixer, and it is usual to have a skip of the same capacity or a multiple of the size

Fig. 5: Placing concrete at Clunie Dam. Note the vibrator and the stiffness of the concrete

of the mixer. Two cu. yd. skips are a common size for the smaller dams. Fig. 5 shows the placing of concrete at Clunie Dam by this method.

Concrete pumps are rarely suitable for dam construction because of the great height and distance of the point of pour from the mixer, and the frequent need for placing several classes of concrete simultaneously.

PLACING CONCRETE.—On the standard size of monolith for large dams the height of pour is usually limited to 5 feet. Higher lifts would probably require special cooling systems to dissipate the heat of hydration, and there is an added disadvantage of high pours, in that the laitance, which always tends to rise to the surface, becomes an objectionably thick layer in lifts higher than 5 feet.

Vibration is desirable for the placing of concrete. High frequency electric immersion vibrators are used; they should be held vertically about 1 ft. 6 in. to 2 ft. 6 in. apart and slowly withdrawn in stages. They should only be used to compact the concrete and not to spread it.

Construction joints, and particularly horizontal joints, form potential paths for the seepage of water through the dam. Extreme care is therefore necessary in the preparation of the concrete surface for each succeeding lift. High-pressure air and water jets are employed to clean the surface and to remove laitance followed by a layer of stiff mortar. Additional precautions are needed if there is a long waiting period between successive lifts on the same monolith, and in these cases it is necessary to treat the concrete surface in a similar manner to the preparation of the underlying rock formation. High-pressure grouting is applied to the interior of the dam to seal up all joints. This process should be left as late as possible, in order to give time for contraction joints to open up by shrinkage.

ACCELERATION OF COOLING.—If successive lifts do not exceed about 50 feet by 50 feet by 5 feet special arrangements for cooling the concrete are not usually necessary. However, some form of accelerated cooling is necessary for larger pours. For example, in T.V.A.'s Douglas Dam[10] river water was pumped through a grid of pipes embedded in the concrete at

5 ft. vertical and horizontal centres. This enabled the concrete to be placed in 10 ft. lifts, with only a 48 hour interval between successive pours. Similarly in Hoover Dam[1], refrigerated water was pumped through a grid of 1 in. diameter pipes.

Although the 44 feet square monoliths of the Rossens Dam[3] were placed in 10 ft. lifts, it was possible to keep the interior temperature down to 46°F. by the use of the 5 ft. diameter ventilation chimney already mentioned. The cooling was aided by evaporation from water sprays on the exterior surfaces and inside the chimneys.

SURFACE FINISHING.—A dense close-knit surface is required on the exposed portions of dams, to resist frost damage, and on spillways, to avoid cavitation in high velocity flowing water, which is liable to cause severe erosion. To obtain well-finished surfaces a fairly rich concrete is required, usually with smaller-sized aggregate than on the interior of the dam. There must be no risk of segregation as this is likely to cause honeycombing of the surface.

To give further improvement special processes have been applied to the surface. Absorptive linings to the shuttering are being used to an increasing extent and were first employed on the Friant Dam[19] in America. The vacuum-process, which draws water from the surface of the concrete, thus giving a high strength and density was first used in 1943, on the spillway of Shasta Dam (U.S.A.).

Reinforced gunite was used for the surface protection of Laggan Dam[5]. In some cases masonry clothing has been used on the exterior of concrete dams, mainly for the sake of appearance. Claerwen Dam[4] will have a squared gritstone rubble facing on the downstream side.

CURING.—The ideal method of curing is a water spray, applied to all the exposed surfaces throughout the curing period. It is desirable to keep the upstream face continuously damp until the structure is filled, in order to minimize temperature stresses due to rapid cooling when filling for the first time.

Compounds giving an impervious coating to seal in the moisture have been used; but they are not so suitable as water spray curing, which assists cooling by evaporation.

Acknowledgments

The information and illustrations of the Clunie Dam are published with the kind permission of the North of Scotland Hydro-Electric Board and their consulting engineers, Sir Alexander Gibb and Partners.

The authors also wish to thank the directors of George Wimpey and Company for facilities given for the preparation of this article.

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Sir Harry Railing

Sir Harry Railing, chairman and joint managing director of The General Electric Company, accompanied by Lady Railing, sailed in the " Pretoria Castle " on Thursday, February 2nd, for an extensive tour of South Africa, during which he will visit the company's offices in Johannesburg, Capetown, Port Elizabeth, Durban, Salisbury and Bulawayo. The chairman is of the opinion that the future of South Africa as a market for British goods depends on our ability to satisfy two demands: the first is for capital goods—both electrical and mechanical—which the Union urgently requires. The second concerns those classes of goods, both manufactured and semi-manufactured, which according to their nature can be more economically supplied from Britain either to secondary industries or to the consumer.

Electrical Engineering Abstract, published by the Institution of Electrical Engineers in association with the Physical Society, the American Physical Society, and the American Institute of Electrical Engineers, included a reference to Mr. C. M. Laffoon's article on hydraulic turbine generators, which appeared in the March-April issue of WATER POWER.

Contractors' Notes

John Blackwood Hodge & Company.—Mr. Ray Armington, president of the Euclid Road Machinery Company, of Cleveland, Ohio, announced at a recent luncheon in the Dorchester Hotel that the Euclid Company had arranged to manufacture equipment in Great Britain and, it was anticipated, the first machine would be available in about nine months' time. Investigations were being carried out to determine the choice of a suitable British power unit for the equipment.

Euclids, he said, would be produced in Britain for world markets, and would be distributed and serviced through the sales organisation of John Blackwood Hodge & Co. Ltd., of 24 Berkeley Square, London, W.1, and associated companies which maintains sales offices and maintenance depots in Europe, Africa, Australia and Asia.

British Thomson-Houston Company.—There has been a notable trend in the hydro-electric field towards the installation of stations which are fully or partially automatic, and not only have orders for new automatic stations been received, but consideration is being given to the installation of automatic control gear for existing sets.

The most interesting order for automatically controlled hydro-electric stations received during the year has come from Dunedin City Corporation and covers the plant for stations nos. 3 and 4 of the Waipori Hydro-Electric Project. The complete project, consisting of four stations, will be a "run of the river" scheme. To enable each station to carry its proper share of the load without waste of water the outputs from stations nos. 3 and 4 are controlled by float switches, the automatic control gear operating to increase or decrease the load of the station as the water level in the forebay increases or decreases. To increase the load on the system as a whole, the top station is caused to increase its discharge and the down-stream stations then automatically increase their output sufficiently to absorb the additional water passing through the system.

The plant now ordered for stations nos. 3 and 4 comprises a 9,000-kVA, 6,000-volt, 3-phase, 50-cycle, 375-r.p.m. vertical shaft alternator for each station; switchgear and the complete automatic starting and control gear, also the supervisory control equipment between the new stations and the control point at station no. 2.

An order has been received from Messrs. Mackness & Shipley, acting on behalf of the Nigerian Electricity Supply Corporation Ltd., for an alternator and switchgear for the Jekko II power station. The alternator is a 5,000-kVA, 750-r.p.m. machine driven by a Boving horizontal Francis turbine; and the station will be remotely controlled from Kurra Power Station. Due to extreme temperature and humidity, and the presence of very fine dust, the conditions at Jekko II power station are particularly onerous. It is proposed, therefore, to enclose all the control gear in dust-tight cubicles, which will be ventilated by filtered air.

Some time ago an order was received from the Crown Agents for the Colonies for stage I of an important hydro-electric scheme in Ceylon. The work on stage I is nearing completion, and instructions have now been received to put in hand the electrical and mechanical plant for stage II. Under stage II the capacity of the generating plant at the power house will be increased from 29,400 kVA to 58,800 kVA., but in order to provide standby the additional generating plant to be installed will comprise three 14,700 kVA, 11,000-volt, 3-phase, 50-cycle, 500-r.p.m. sets. The arrangement of 11-kV and 66-kV switchgear and of the 1,500-kVA transformer banks supplied for Stage I will be duplicated, as will an 8,000-kVA synchronous condenser in the receiving station at Colombo.

A further order has been received from Messrs. Balfour Beatty for the Tana Power Station of the East Africa Power and Lighting Company. This order covers a 3,000-kVA, 600-r.p.m. horizontal waterwheel alternator, which is a duplicate of two machines supplied in 1931 except for minor changes to modernize the construction.

Bruce Peebles & Company, Edinburgh.—One of the most significant pointers to the company's activities in hydro-electric work during 1949 was the large number of contracts undertaken for generators of big output for projects at home and abroad, many of which carried full responsibility for both the electrical aud hydraulic sides. Among work of this kind in hand of more than ordinary interest are several complete hydro-electric plants in units up to 21,000 kW for the Scottish Highlands. Work is also proceeding on numbers of units in sizes up to 11,200 kW for various water power projects in Norway; and on two 10,000 kW generators, 15,000 kVA, and 10,000 kVA synchronous condensers for hydro-electric schemes in New Zealand.

The past year has seen the completion of the first of two 12,000 kW vertical generators for the Loch Fannich scheme of the North of Scotland Hydro-Electric Board. Shipments oversea of hydro-electric plant included a 3,000 kW slow speed unit for Colombia, South America; and 2100 kW, 1600 kW, and 1040 kW units for various schemes in Norway.

Among other large transformers completed during 1949 emphasis is placed on a 60,000 kVA three-phase bank of 132 kV single phase water-cooled units for the Clunie power station—Tummel-Garry project—and two 20,000 kVA three-phase units for the Loch Fannich scheme of the North of Scotland Hydro-Electric Board.

The Brush Electrical Engineering Company. — Through its agents, Messrs. Clyde Engineering Limited, Wellington, New Zealand, the company has been entrusted with an order for two 20,000 kVA banks of transformers, 66/11 kV, complete with "on-load" tap-change gear. These transformers are destined for the Papanui sub-station of the State Hydro-Electric Department, New Zealand.

The English Electric Company.—In the early part of 1949 the North of Scotland Hydro-Electric Board placed an important contract with the company for generating plant for the five power stations comprising the Garry Morriston Scheme in Inverness-shire. For three of the power stations—Invergarry, Invermoriston and Ceannacroc—the company it supplying both the turbines and the generators, and in two of the stations, Quoich and Dundreggan, it is supplying the generators.

The scheme as a whole is now being finalized by the Board entailing some modification to the number and size of units and, in certain cases, to the technical data, but the following table shows the particulars of the plant as originally ordered:—

Station	Net Head Ft.	No. of Units	kW Output Each Unit	r.p.m.
Invergarry ...	198	2	12,000	300
Invermoriston ...	174	2	10,000	300
Ceannacroc ...	252	1	13,500	300
Quoich ...	287	2	10,000	428
Dundreggan ...	113	1	13,000	250

In the course of the year the Company has also received two comprehensive contracts for Spain. One of these was placed by Saltos de Navia en Comunidad Oviedo, and consists of generating plant, transformers and switchgear for Salime Power Station on the River Navia. The plant comprises four 34,000 h.p. vertical reaction water turbines operating under a head of 69 metres and running at a speed of 300 r.p.m. The four generators are each designed for 32,000 kVA, 11 kV, 50 cycles. At the switching station there are four step-up transformers each 32,000 kVA, 11/132 kV, and complete 132 kV switchgear with air-blast circuit-breakers.

The other contract was placed by S.A. Hidroelectrica Espanola and consists of generating plant and switchgear for Picazo Power Station situated on the River Jucar about 200 miles east of Madrid. There are two 12,850 h.p. vertical reaction water turbines, 47.65 metres net head, equipped with "straightflow" inlet valves and driving 10,500 kVA vertical generators, 9,450 kW at 0.9 power factor, 12.3 kV, 50 cycles, at 300 r.p.m. The station will be unattended and completely automatic, being controlled from Olmedilla Switching Station about 12 miles distant.

Another order consists of three 22,000 h.p. horizontal impulse turbines, 1,474 ft. head, 500 r.p.m. for the Ceylon Government for an extension of the Aberdeen-Laxapana Scheme for which The English Electric Company has recently supplied three turbines of rather smaller output. An interesting development during the year has been the receipt of an order by John Inglis & Co. of Toronto from the Ontario Hydro-Electric Power Commission for two 33,000 h.p. vertical reaction turbines, 77 ft. head, 94.7 r.p.m. to be manufactured by John Inglis to "English Electric" designs.

Steady progress has been made with the erection of the four 45,500 h.p. vertical reaction units, 810 ft. head, for the Loch Sloy Power Station of the North of Scotland Hydro-Electric Board, and erection work has also been proceeding on the three 31,500 h.p. vertical reaction sets, 490 ft. head, for the Mullardoch-Fasnakyle-Affric station of the Board.

In the export field erection of the 30,000/35,000 h.p. vertical feathering propeller unit, 74/96 ft. head, for the Tekapo power station of the Public Works Department, New Zealand, has been proceeding during the year. The Waddamana "B" power station of the Hydro-Electric Commission of Tasmania has now been completed and the four 16,700 h.p. horizontal impulse set, 1,070 ft. head, 500 r.p.m., are now in operation. The turbines are of the two-runner four-jet single casing type. The runner has integral buckets cast in one piece and the turbines are fitted with the Seewer system of double regulation, cylindrical balanced inlet valves and aerofoil recorders.

Erection has also been proceeding during the year on the two important Portuguese contracts, Hidro-Electrica do Zezere for Castelo do Bode and Hidro-Electrica do Cavado for Vila Nova. These contracts are being executed jointly by the English Electric Export and Trading Company and Metropolitan-Vickers Electrical Export Company. The former consists of three 73,000 h.p. vertical reaction units, 174/312 ft. head, 214 r.p.m., together with "straightflow" inlet valves, main transformers and 150 kV switchgear. The other contract comprises three 39,000 h.p. horizontal impulse type units, 1,360 ft. head, 428 r.p.m., with "straightflow" inlet valves, step-up transformers, and 150 kV switchgear, together with pipelines, cranes, gates, and discharge valves.

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The name of **Transport (1910) Limited,** of 33, Tothill Street, Westminster, S.W.1, has been changed to **Tothill Press Limited.** When the company was formed its publications dealt exclusively with the transport industry. With the development of its publishing interests the need for a more representative title of the company's activities has become evident.

Apart from WATER POWER, the company publishes: *The Railway Gazette, Shipbuilding and Shipping Record, Colliery Engineering, Power and Works Engineering, The Industrial Chemist, Building, Food, The Crown Colonist, Wood, Diesel Railway Traction, Coke and Gas, The Railway Magazine, Directory of Railway Officials and Year Book,* and the *Directory of Shipowners, Shipbuilders and Marine Engineers.*

Recently a number of subsidiary companies of Transport (1910) Limited were wound up and the assets transferred to the parent company. They included the St. Margaret's Technical Press Limited, Nema Press Limited, the Directory Publishing Co. Ltd., and the Railway Publishing Co. Ltd.

In September, 1945, control of Transport (1910) Limited passed to Odhams Press Limited.

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